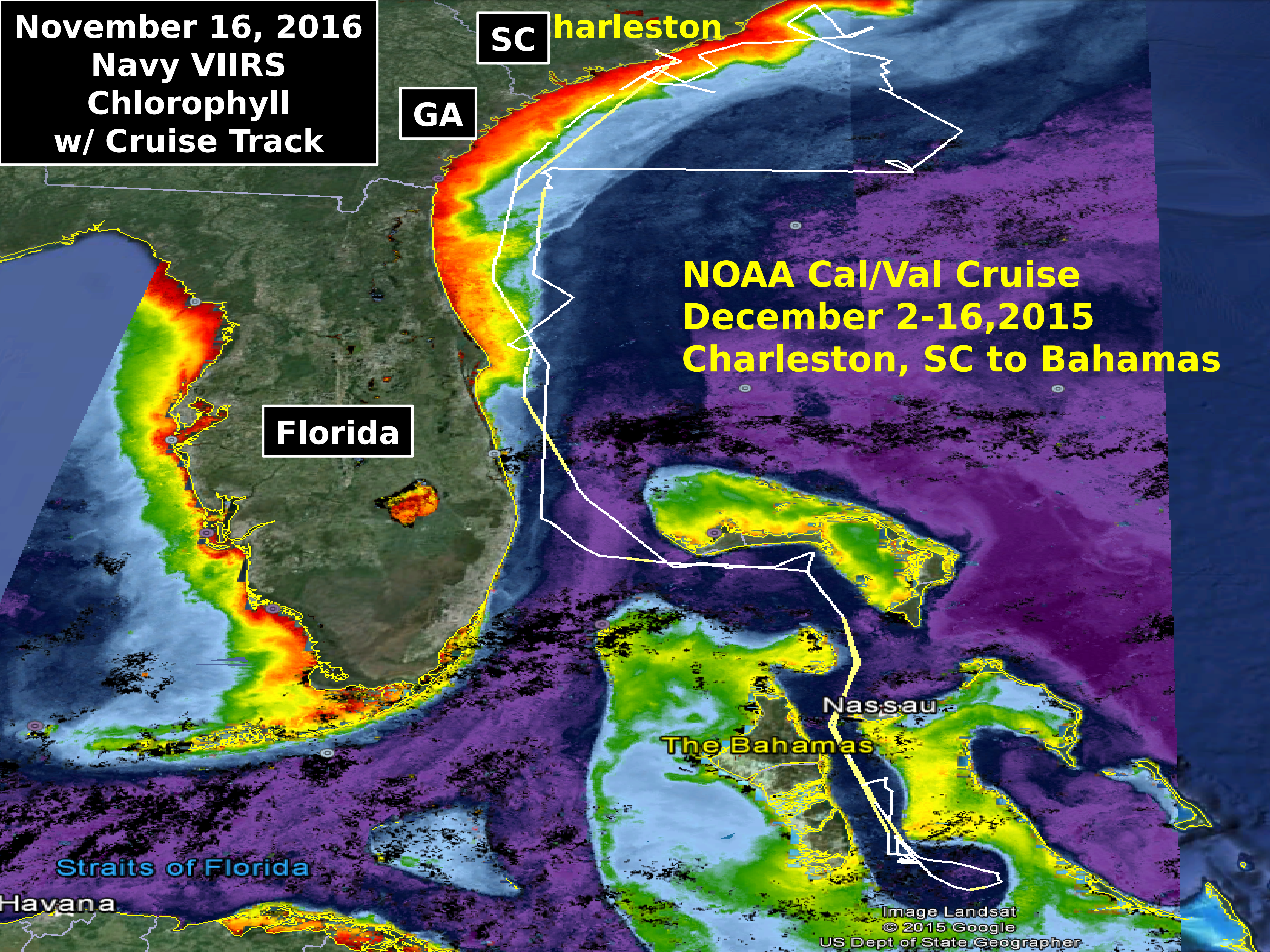
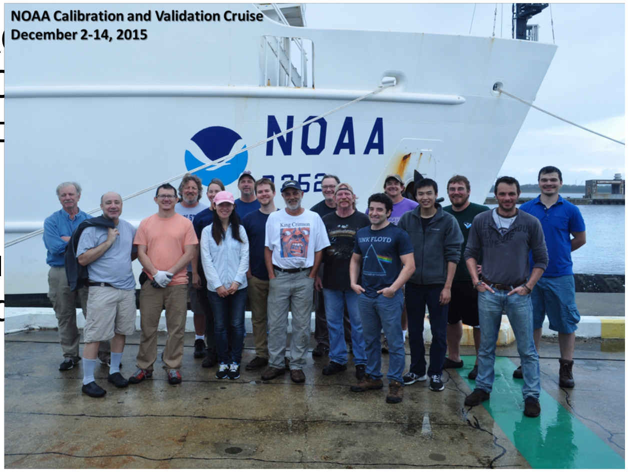

November 16, 2016
Navy VIIRS
Chlorophyll
w/ Cruise Track
SC
harleston
GA
Florida
NOAA Cal/Val Cruise
December 2-16,2015
Charleston, SC to Bahamas
Nassau
The Bahamas
Straits of Florida
Havana
Image Landsat
© 2015 Google
US Dept of State Geographer

nnis ACS (WETLabs) Protocols – Underway Flowthru D

- Collection
  - Non-Filtered ACS, Filtered(Cole Palmer 0.2 micron filter) A Thermosalinograph, Fluorometer and Backscattering (EC
  - Thermosalinograph necessary for temperature and salinit of AC measurements
  - Water pumped from ~3m depth
  - 3 Nanopure Water Calibrations (1 before and 2 during cru
  - DH4 used to log all flowthru instruments (hourly files) anc real-time using Wetview
  - WAP used to time merge all flowthru data



- Processing (WETLabs 2011 Protocols)
  - Interpolate ACS (Filtered and non-Filtered) absorption and beam-c data to same hyperspectral channel set (c1)
  - Temperature and Salinity correction of ACS absorption and beam-c using coincident ship flowthru Thermosalinograph data
  - Temperature correct nanopure water calibration file
  - Subtract the nanopure water calibration from the ACS data (absorption and beam-c)
  - Remove spikes normally caused by bubbles in system using a standard deviation filter (x4) – all records removed
  - Compute Particulate Absorption: $a_p = a_t$ (non-filtered ACS) – a_g (filtered ACS)
  - Apply scatter correction (Rottgers 2013) to a_p
  - Add scatter corrected particulate absorption (a_p) to CDOM absorption (a_g) yielding total absorption without water (a_{t-w})
  - Add spectral pure water absorption coefficients (a_w) to total absorption without water (a_{t-w}) yielding total absorption (a_t).
  - Particulate absorption (a_p), spectral scattering (b), omega (b/c) can be computed/created in spreadsheet (not written to corrected/processed files).

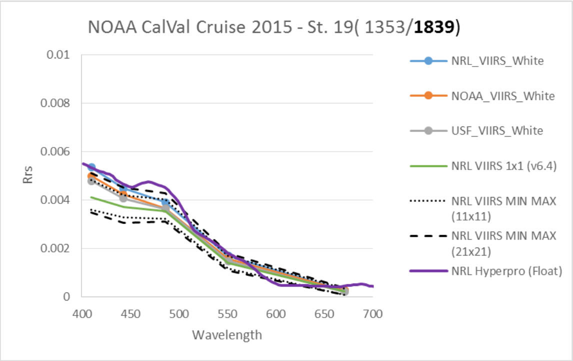
s ACS (WETLabs) Protocols – Underway Flowthru Data

- Cruise Flowthru Objectives
  - Characterize the spatial variability of the water's optical properties (a,b->bb,c) along the cruise track and how the variability impacts the uncertainty of insitu measurements at each station and ocean color response.
  - Determine the water total and dissolved absorption (at, ag) properties at specific wavelengths
  - Define frontal boundaries (Gulf Stream and Coastal Fresh Water/Upwelled Areas) using Thermal, Biological and Optical Properties
  - Validate VIIRS Temperature, Salinity, Chlorophyll and IOP (QAA/LMI) products.
  - Define ocean processes and water mass types
  - Validate the spatial variability with a VIIRS 750m pixel by binning (mean &

Figure - IOP setup shows water bath setup using the acs, ac9 instruments. The ac9,acs are located inside the PVC containers and were in a controlled/constant temperature bath during operation.

Stennis ASD Protocols

- <u>Setup (FLDSPEC Software) w/ Protocol</u>
  - Foreoptic / FOV = 10deg, #scans + dark currents each set (water, sky, reference plaque) = 5, Optimize before each set, Reference = 10 inch 10% reflectance gray card, #stations = 18, #station collects = 26,
  - NRL, NOAA, USF ASDs set up and operated by S. Ladner (NRL)
  - NRL, USM, NOAA, USF, CCNY was collected using same protocols and using NRL reference plaque. Groups also collected a set using their own reference plaque and maybe protocol?

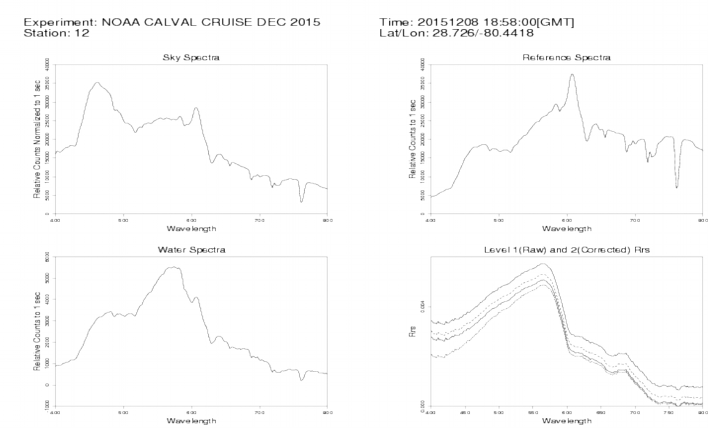


- <u>Collection Sequence</u>
  - Optimize gray reference plaque then collect 5 spectra
  - Optimize water then collect 5 spectra and DCs
  - Optimize sun then collect 5 spectra and DCs
  - Optimization changes integration time based on relati
    brightness of target
  - Optical zenith angles for reference, water, sky = 135,
  - Relative sensor azimuth angle to the sun = >90 deg (
    avoiding shading/shadows from ship, surface contam
    glint, foam, etc.)
  - Integration times ranged from 68 to 4352ms
  - All groups/measurements were taken from Bow or Mi
    01 deck and on starboard side unless sun/ship orient
    forced collection to port side
  - All groups shot same grey reference plaque (NRL) and from same
    location on ship

<u>Figure:</u> Ryan Vandermeulen (NASA) and Robert Arnone (USM) aboard the NOAA Ship *Nancy Foster*, taking ASD measurements reference plaque

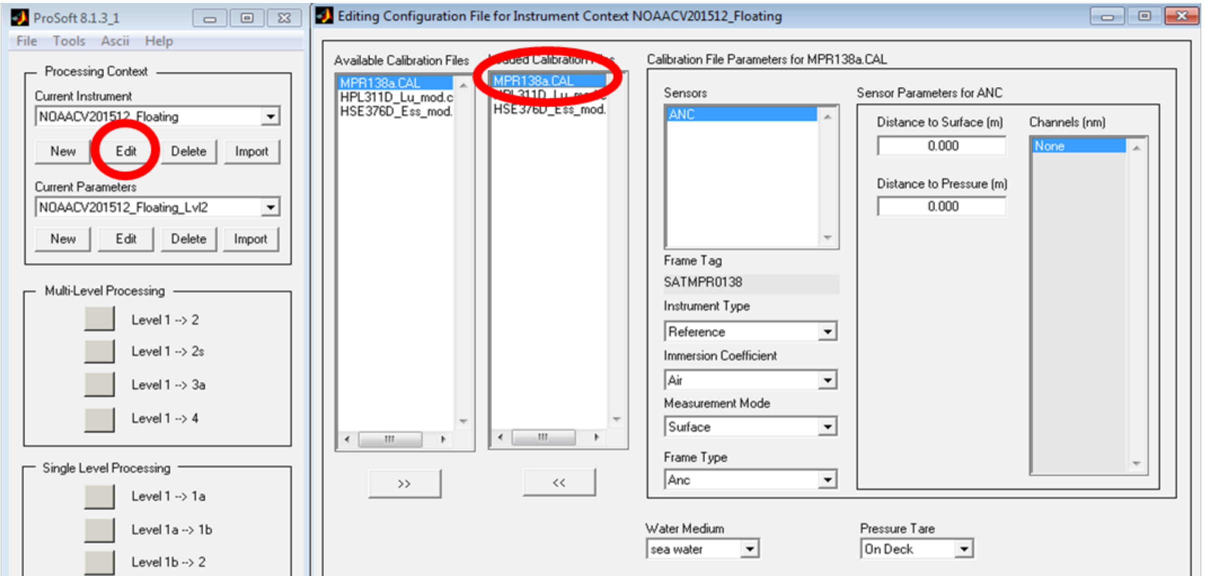
Stennis ASD Protocols (Cont)

- <u>Processing</u>
  - Grey reference plaque has a know BRDF for normalizing the un-calibrated radiance measurement for Es
  - Deriving Rrs from above water radiometry follow optics protocols from Mueller 2003 (Chapter 3 – Method 2) $S = \frac{\sum_{i=0}^{n} C I_N / I_i}{n}$
  - Sensor response signal (S) / reflectance is obtained from averaging N (5) readings from each of 3 targets and normalized to 1sec integration time $L_W = F_L (S_{sfc} - \rho S_{sky}), E_S = \frac{\pi F_L S_g}{R_g}$ C = corrected DC from Instrument, I_i is the integration time used for that reading, I_N is the normalized (1 second) integration time, N is the reading number.
  - Water-Leaving Radiance (L_w) and Incident Spectral Irradiance (E_s) $R_{rs}(\lambda) = \frac{S_{sfc}(\lambda) - \rho S_{sky}(\lambda)}{\pi S_g(\lambda) / R_g(\lambda)}$, F_L = unknown instrument radiance response calibration which cancel out in ratio for computing Rrs, R_g = gray reference plaque's bi-directional reflectance function (albedo)
  - Rrs can be computed from the un-calibrated instrument data using , *p* = Fresnel Reflectance for sky correction
  - The preferred Rrs correction (white) assumes from Carder and Steward 1985 that Rrs at 750nm should be black / zero. If not zero, then it is assumed that the error in the reflected skylight term (S_{sky}) was not estimated correctly and is white (not wavelength dependent) and may be subtracted from entire sp negative reflectances in the NIR channels. Therefo smallest Rrs in the range from 700 to 825nm, $R_{rs}(\lambda) = R_{rs}(\lambda) - MIN(R_{rs}(700\ to\ 825))$
  - For comparison to SNPP VIIRS the hyperspectral AS VIIRS Relative Spectral Response (RSR) table for ea This RSR table (VIIRSN_IDPSv3_RSRs.txt) was ext NRL's APS software (based on NASA's SeaDAS – L originated from the IDPS.
  - <u>*Blue Tile:*</u> Slight modifications were made to the ec derive the relative reflectance of the blue tile (R_{til} $R_{tile}(\lambda) = R_g(\lambda) \frac{S_{tile}(\lambda)}{S_{ref}(\lambda)}$ blue tile measurements, the derived reflectance is simply expressed as the ratio of the radiance (or net signal) for the



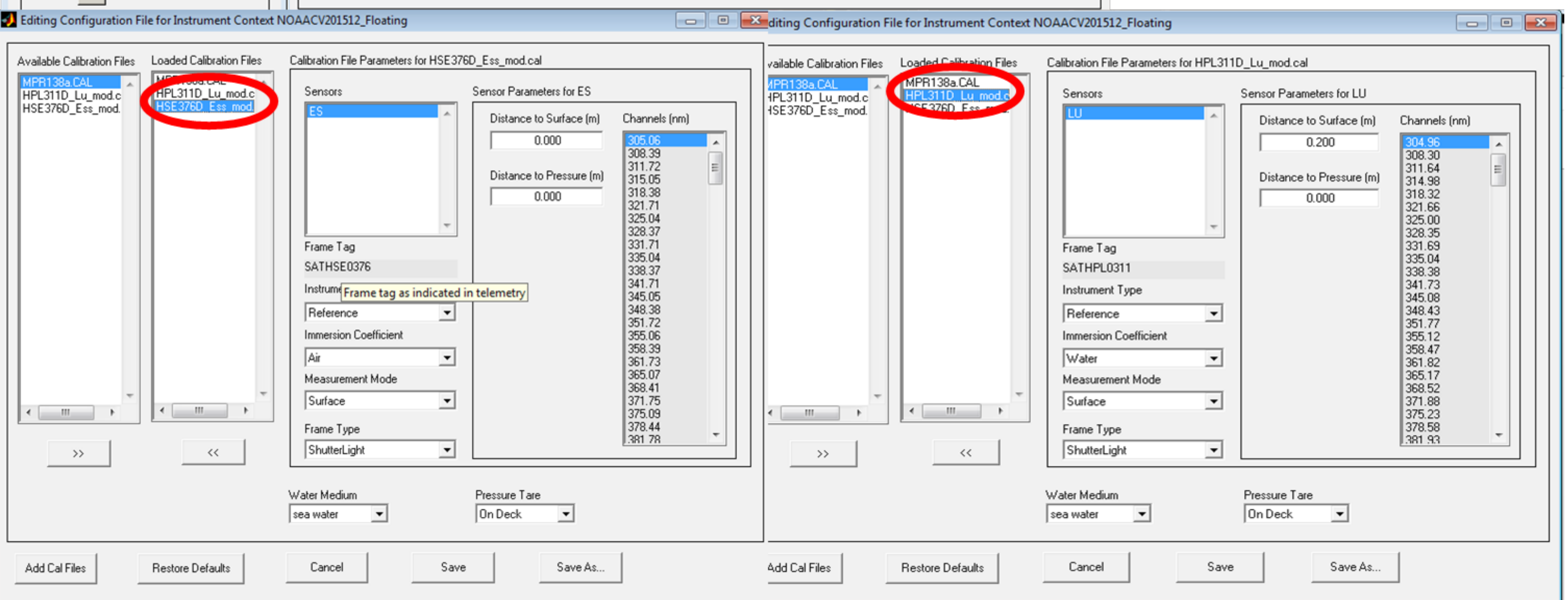
Stennis Hyperpro (Satlantic) Protocols

Need to define processing protocols



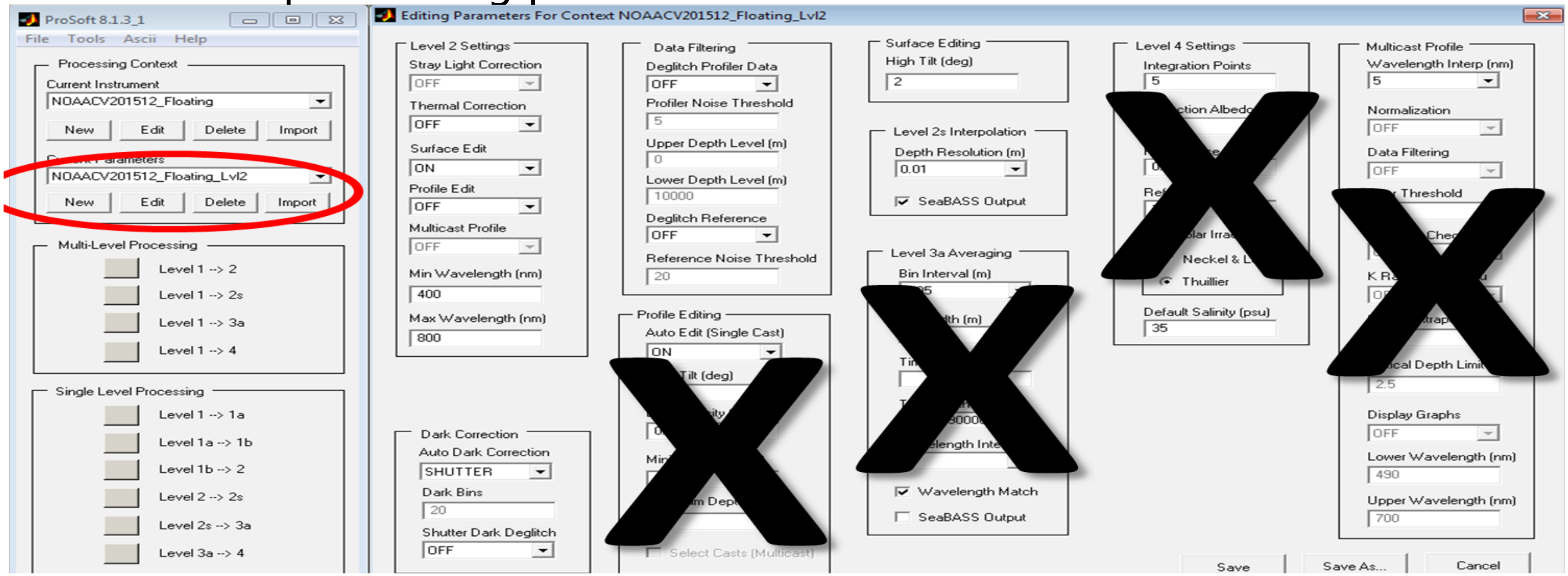
Example using NRL Hyperpro Setup.

Surface Time Series



Stennis Hyperpro (Satlantic) Protocols (Cont)

Need to define processing protocols



X = Not used for floating package for this version (1.8.3) – Only level2 output worked yielding calibrated radiances.

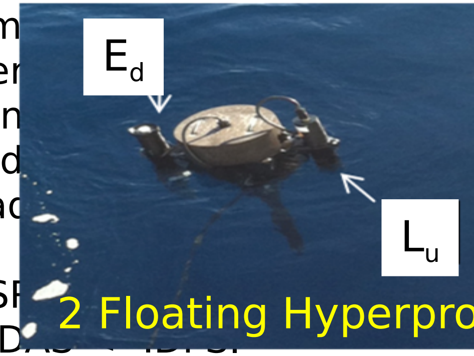
Prosoft v8.1.3: errors generating Level 3 time series files – output just one record instead of all temporal samples.

Prosoft v8.1.4 (Notes from Prosoft Support Team / Darrell Adams) - New version w/ bugs fixed:

Level 3a processing of this data is possible if the Level 3a processing parameters are set appropriately. Time Interval and Time Width should not be set to 0 and 9000 respectively. For example when the Time Interval is set to 2 seconds and the Time Width is set to 1 second there are Level 3a data that is written to HDF and ASCII output files for each optical sensor (ie. Es and Ls). To output Lu, Ed, and Es at Levels 2s and 3a when all sensors are configured to be a "Reference" instrument type is possible if the Measurement Mode for all three is set to "Logger" in the Instrument Context. To have the Ed and Es (Irradiance optical sensor) wavelengths matched up to the Lu (radiance optical sensor) wavelengths the Level

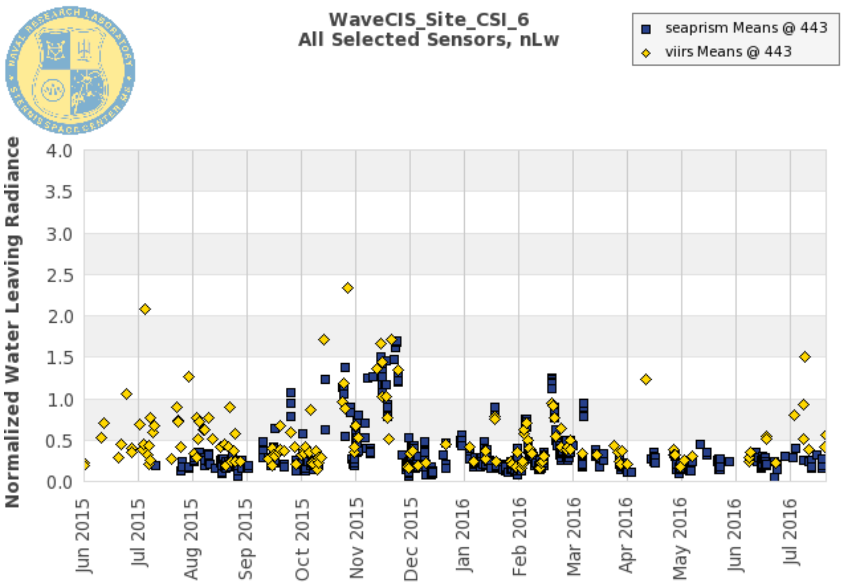
Stennis Hyperpro (Satlantic) Protocols (Cont)

- Collection/Processing Rrs
  - Floating HyperPro is a hyperspectral profiling radiometer that sim measures above-water downwelling irradiance (Ed) and in-water radiance (Lu) on a fixed floating platform and downwelling Es on
  - Used to measure the hyper-spectral normalized water leaving rad computed using Thuiller hyperspectral extraterrestrial solar irrac Rrs = nLw(lamda)/F0(lamda)
  - Both hyperspectral nLw and F0 were convolved to SNPP VIIRS RSF (VIIRSN_IDPSv3_RSRs.txt) obtained from NRL APS <- NASA SeaDAS <- IDPS.
  - Collected measurements at 21 stations.
  - The spectral range of both Esd and Lu sensors is from 350 nm to 800 nm with 10 nm ± 0.3 nm resolution.
  - These instruments were used with a molded floatation collar, enabling in-water surface measurements to be taken over time just below the sea surface.
  - The downwelling Ed sensor uses a cosine collector and is approximately 30 cm above the water surface which is different from ASD sky measurement.
  - The upwelling (Lu) radiance sensor is mounted approximately 30 cm below the water surface.
  - The ship mounted Es sensors was an cosine collector was mounted on the 01 deck with the other Hyperpros and was used for the downwelling computation of Rrs to omit uncertainty in the Ed (on the floating instrument) due to tilting caused from sea state and tension on the line.
  - The USM Hyperpro was calibrated by NOAA- STAR in Oct 2015. The NRL Hyperpro was calibrated by NOAA STAR in Dec 2015. Calibration was similar to the Saclantic values and no major change was noted.
  - The Floating HyperPro was deployed over the stern of the vessel. The tether was let out a sufficient distance from the boat (20 m to 30 m), allowing the instrument to float away from the boat to omit contamination from vessel-generated bubbles and shadowing or any other potential disturbances.
  - Measurements were made over 5-10 minute time period.

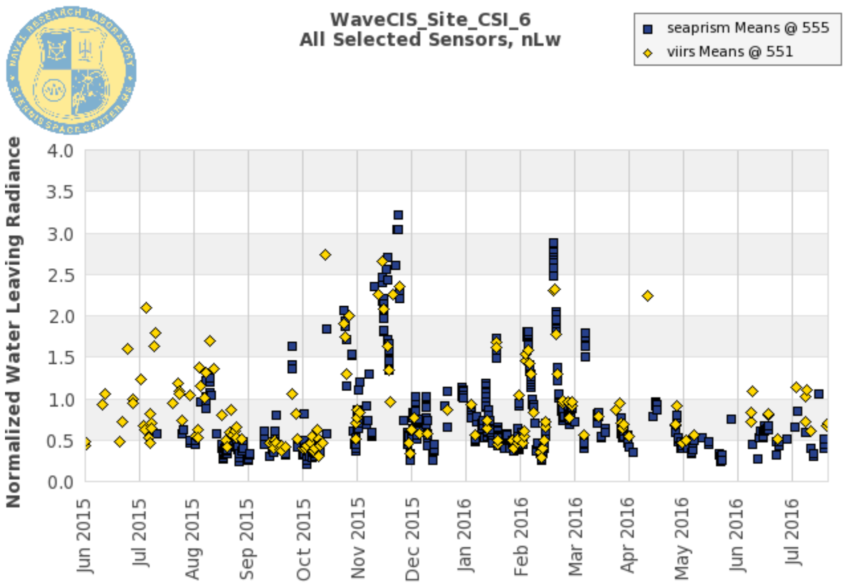


WaveCIS nLw FULL Time Series: NAVY APS 6.4
July 2015 – July 2016

443

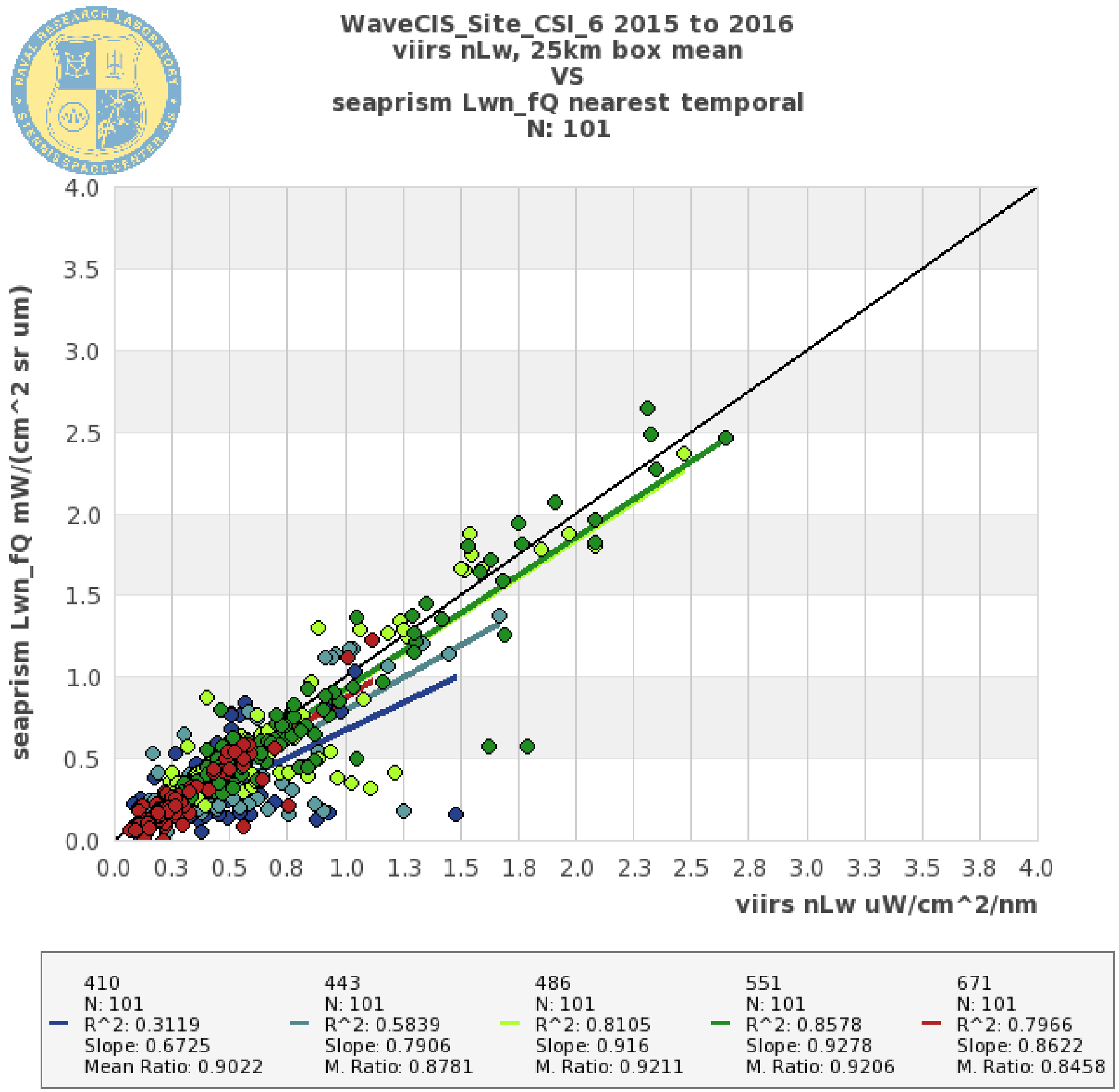


551

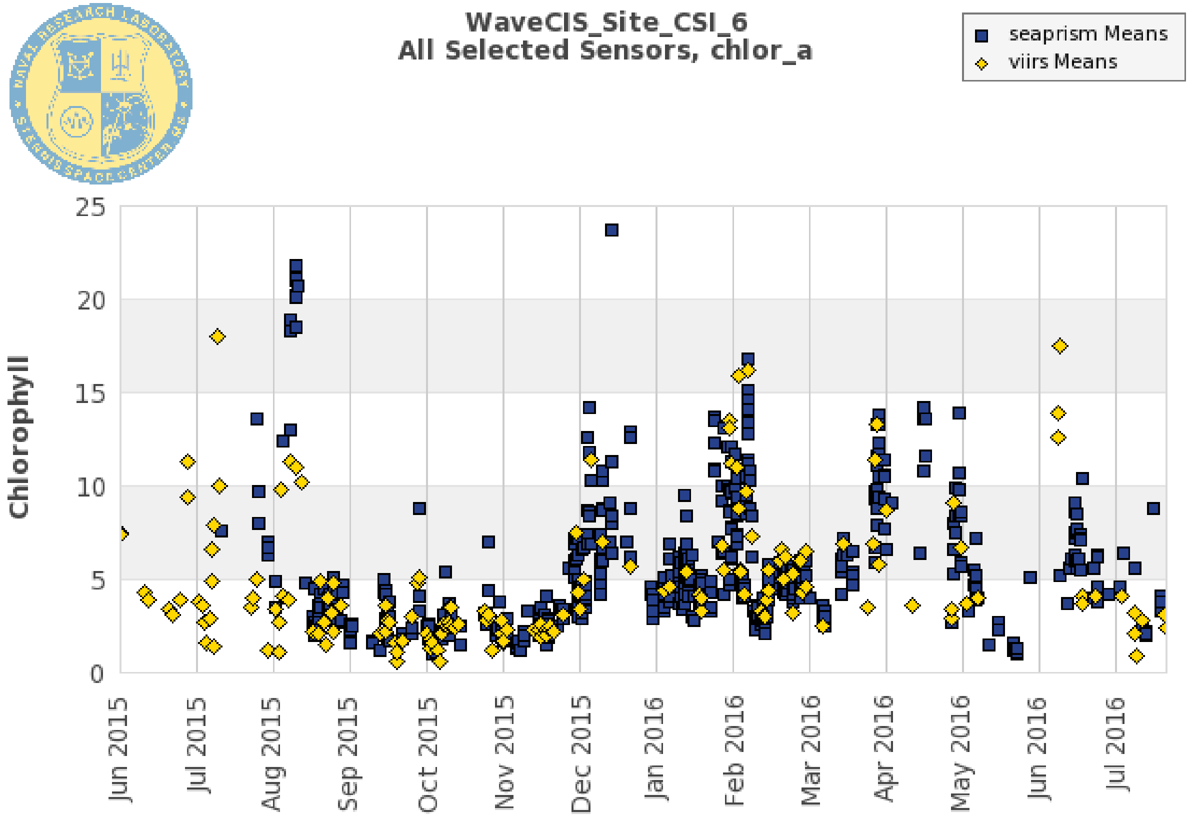


These are constrained results: 163 for VIIRS and 692 for WaveCIS (4-6 readings/day)

WaveCIS nLw Matchups (NAVY APS)
July 2015 – July 2016

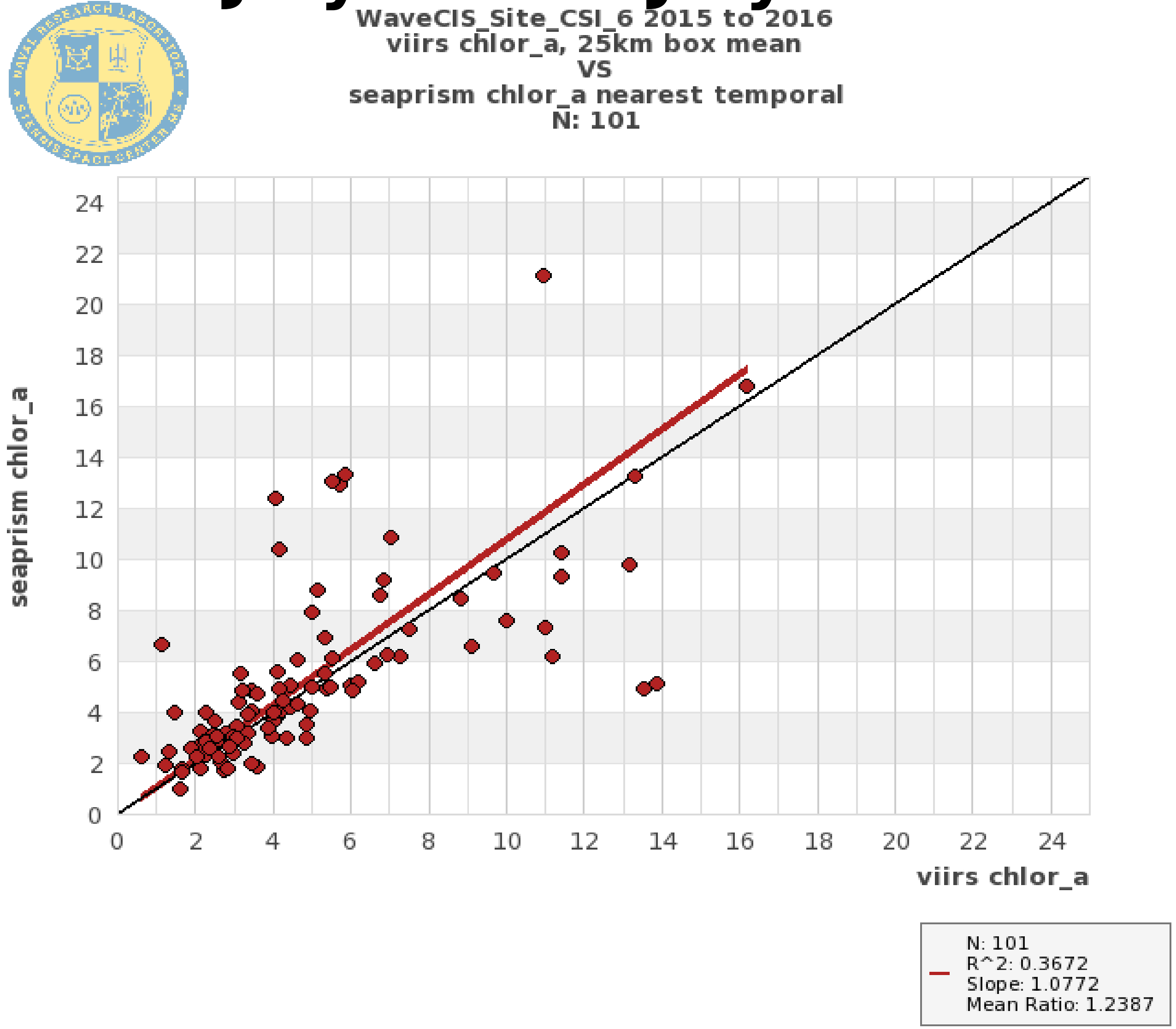


WaveCIS FULL Time Series: NAVY APS 6.4
Chlorophyll



These are constrained results: 163 for VIIRS and 692 for WaveCIS (4-6 readings/day)

WaveCIS Chlorophyll Matchups (NAVY APS)
July 2015 – July 2016



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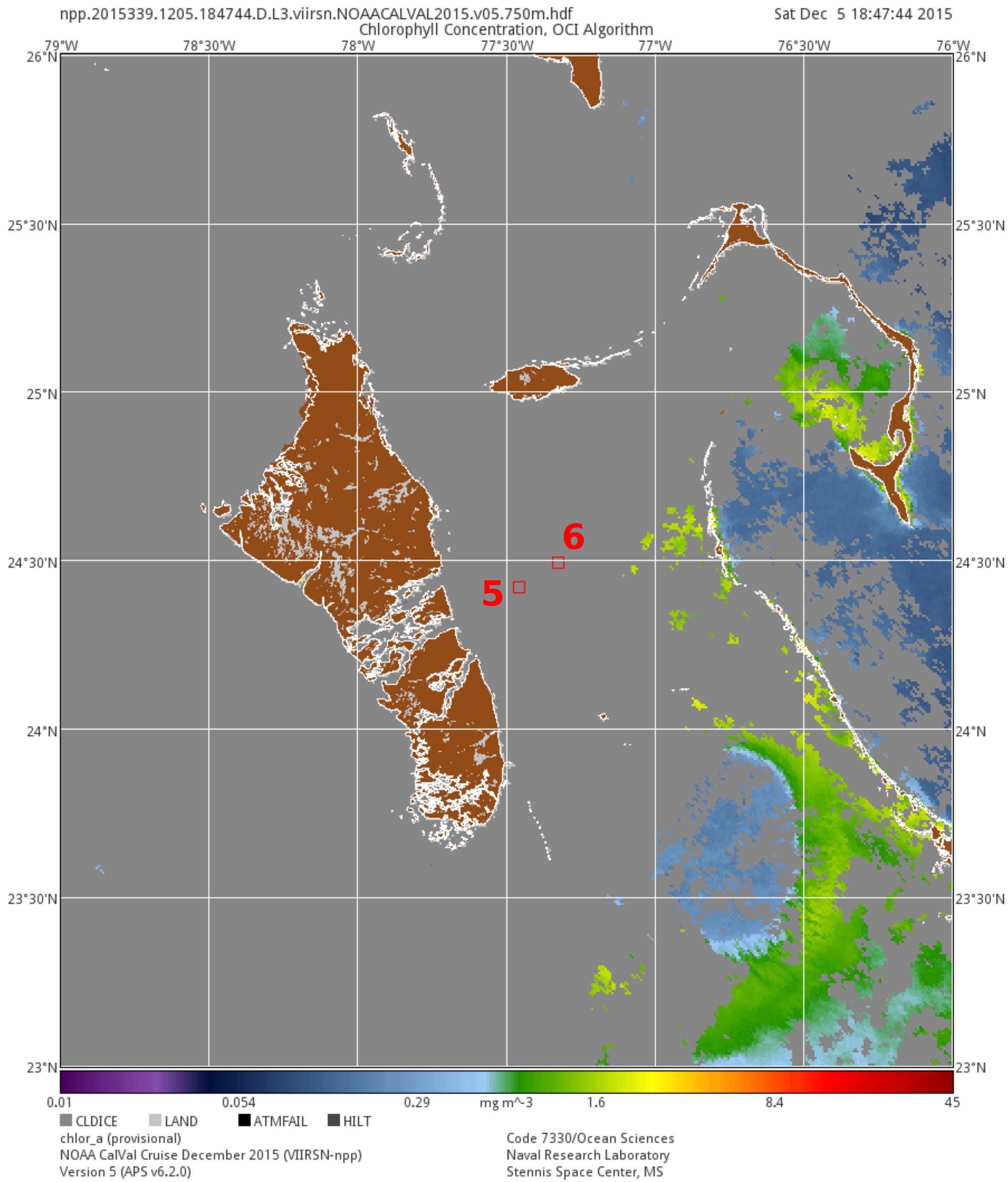
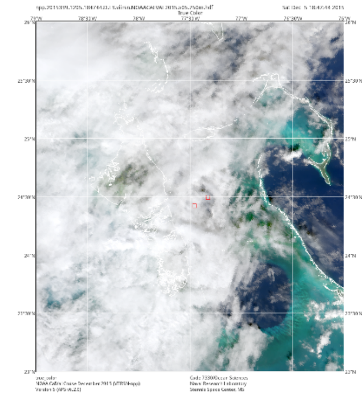
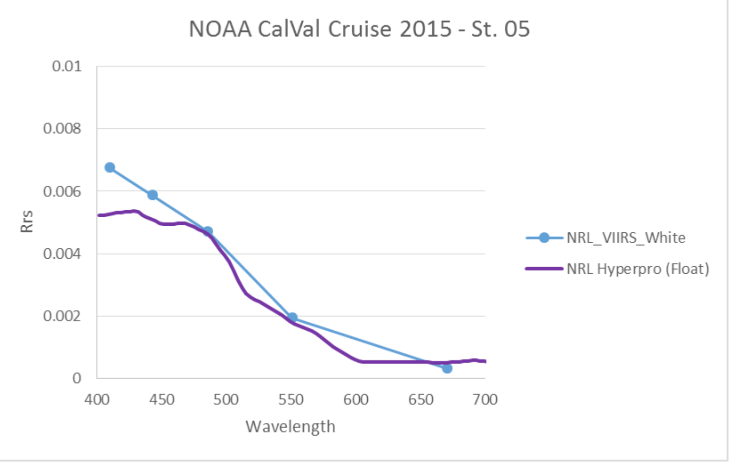
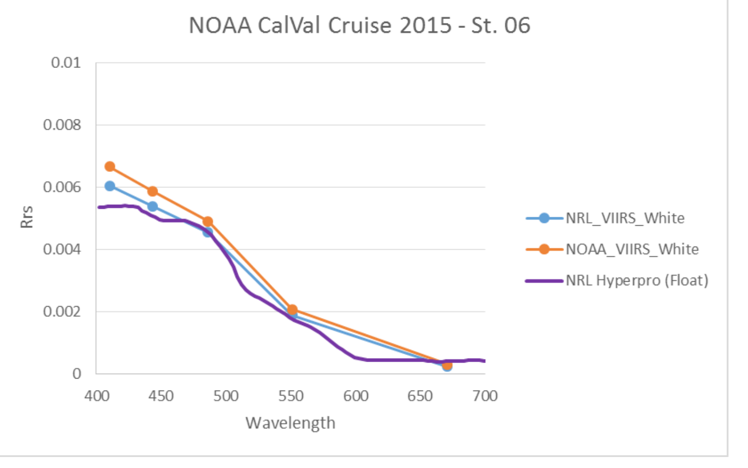
St. 5,6

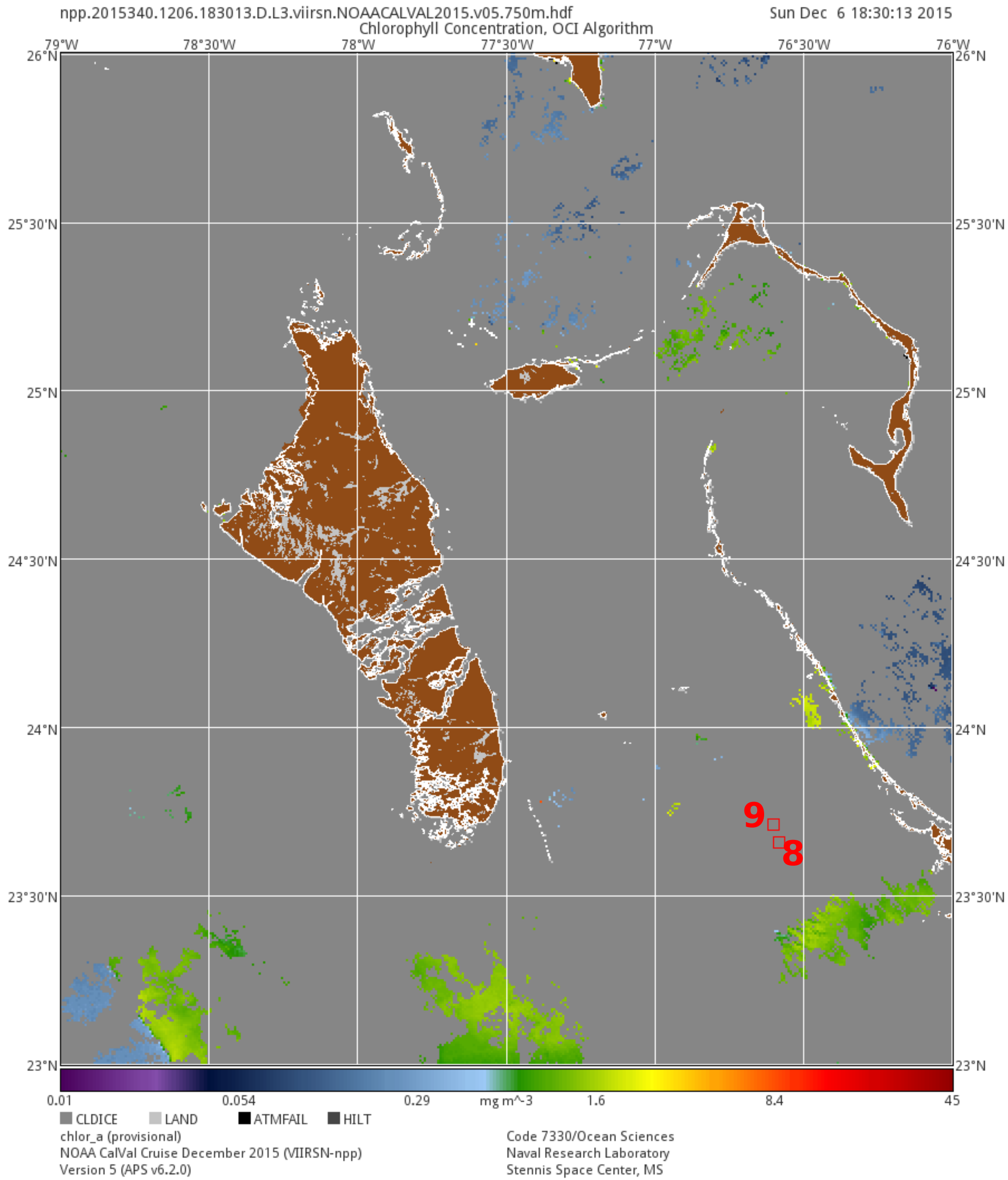


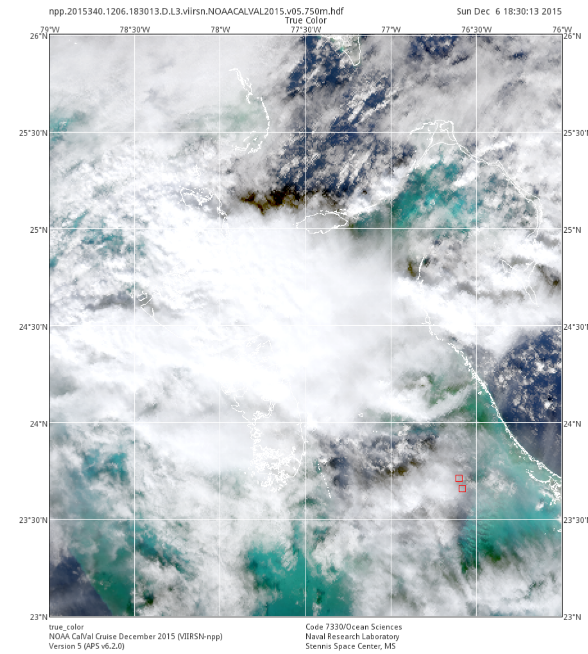


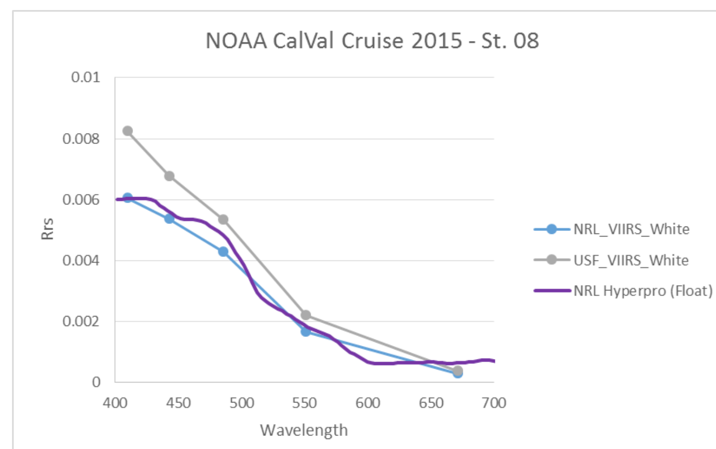




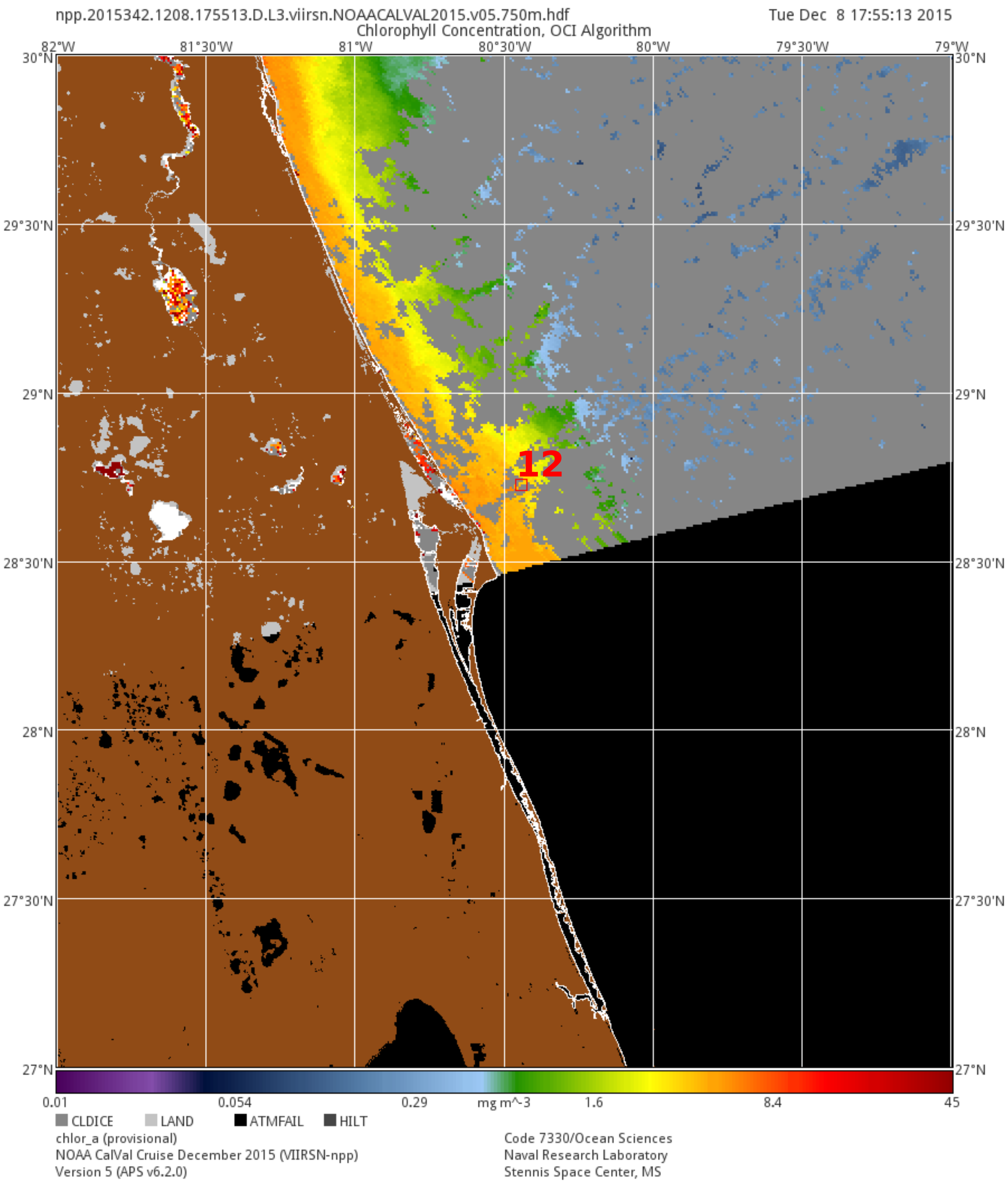
12/06/16 (1830 GMT)
St. 8,9

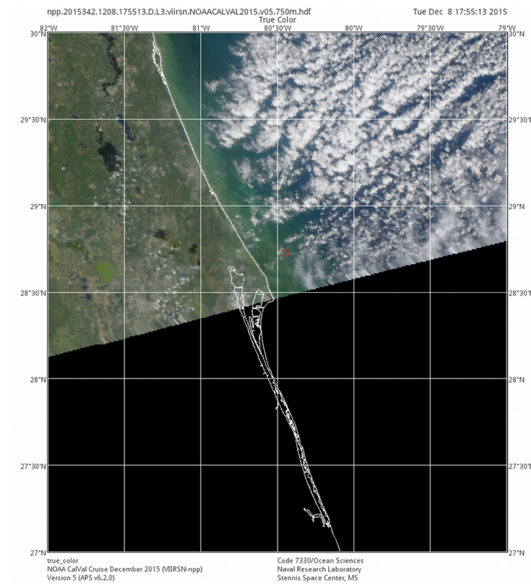


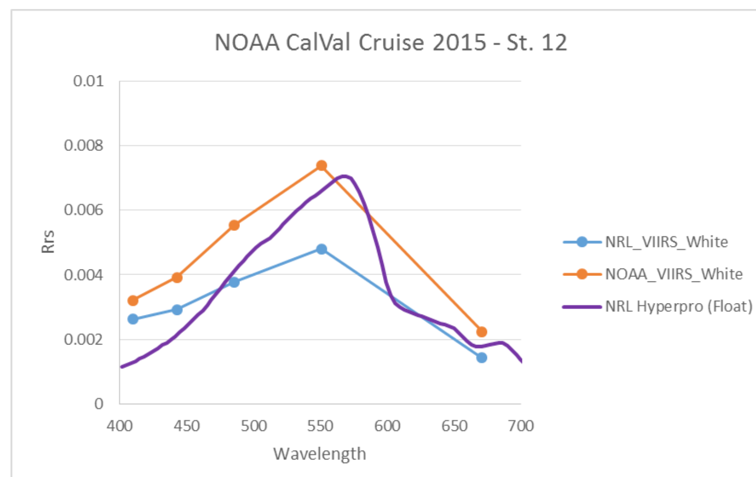




12/08/16 (1755 GMT)
St. 12



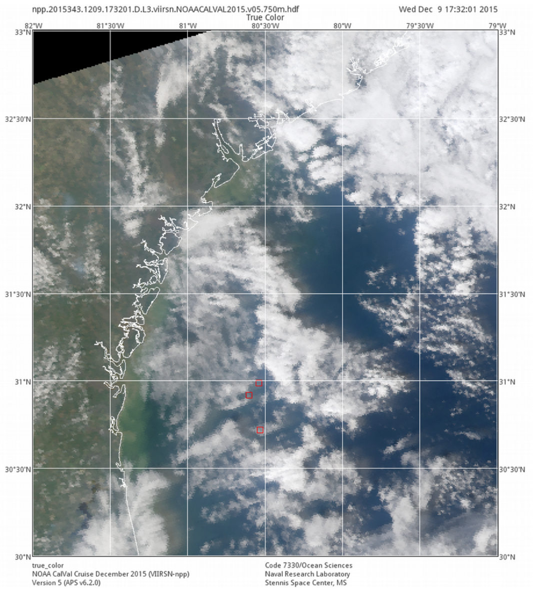


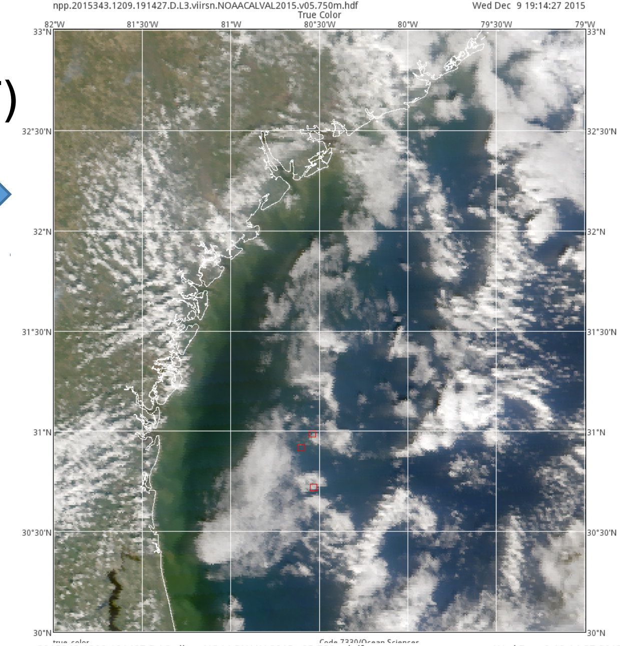


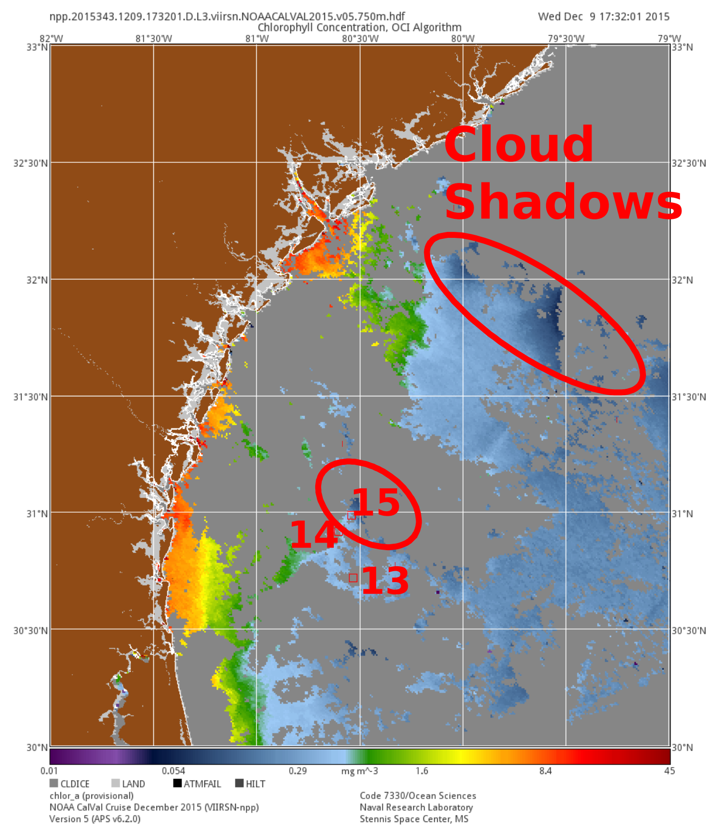
12/09/16 (1732/1914 GMT)
St. 13, 14, 15

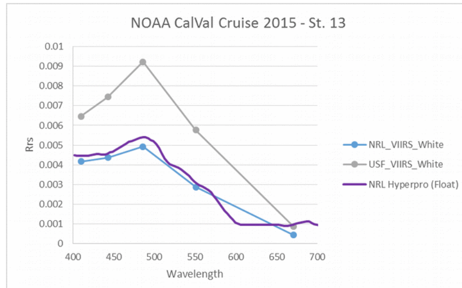
1732

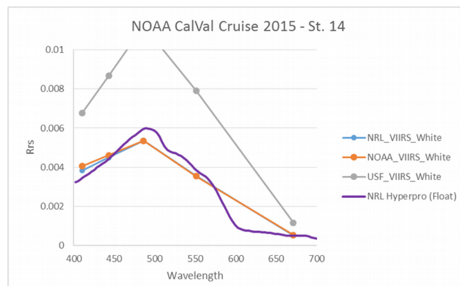
1914

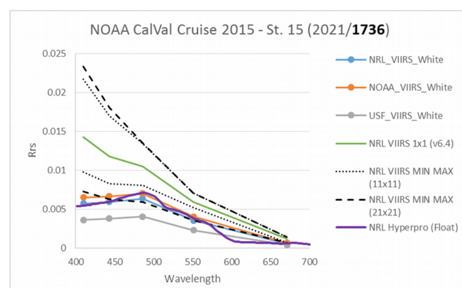


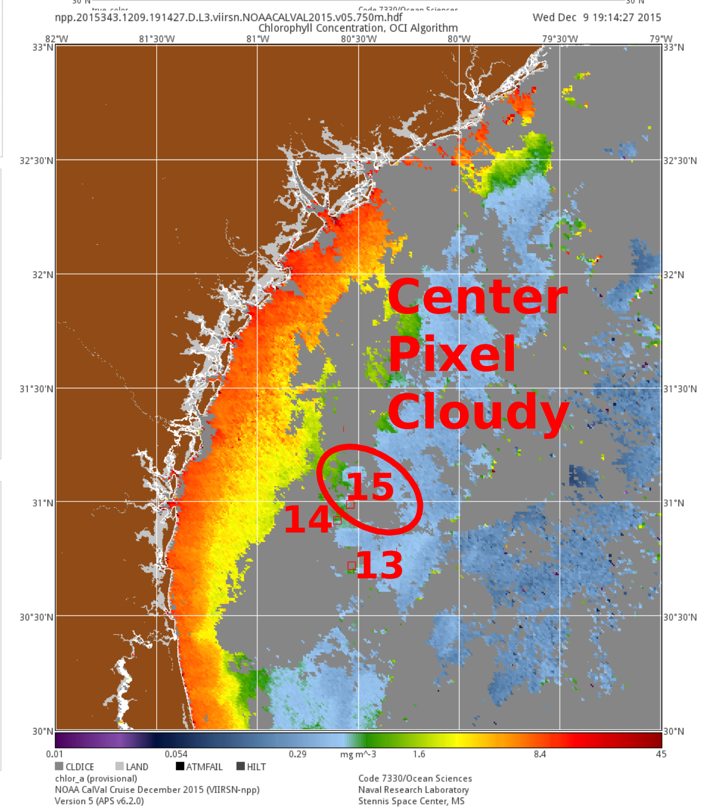




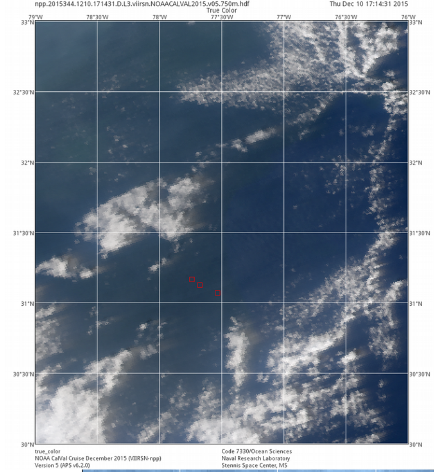






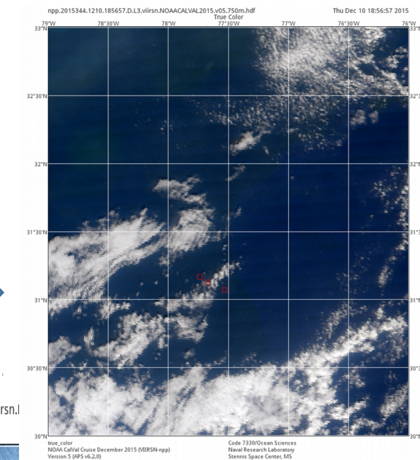


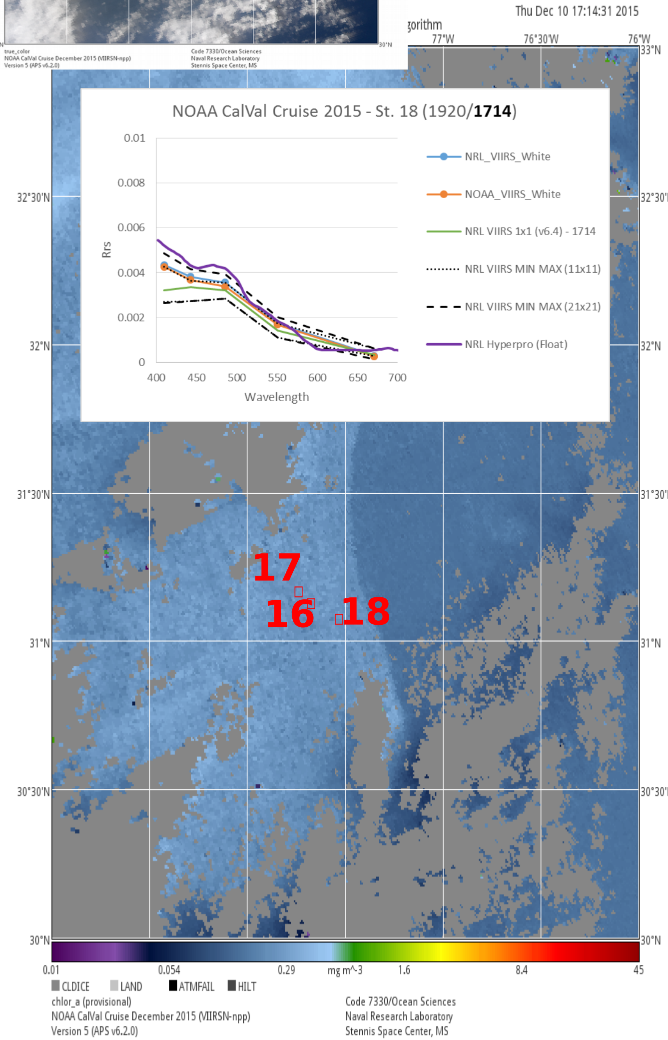
12/10/16 (1714/1856 GMT)
St. 16,17,18

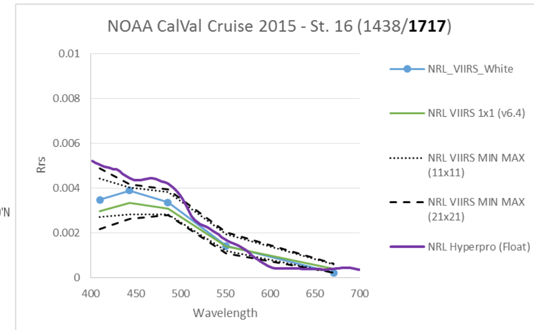


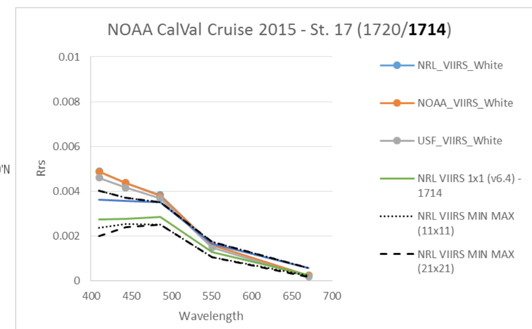
1714

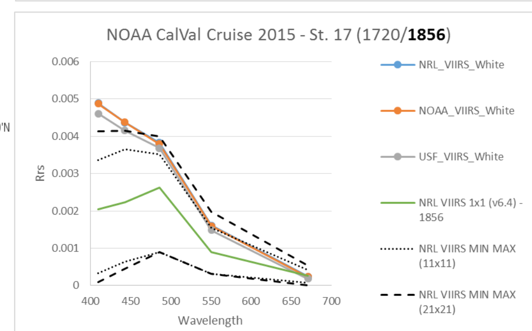
1856

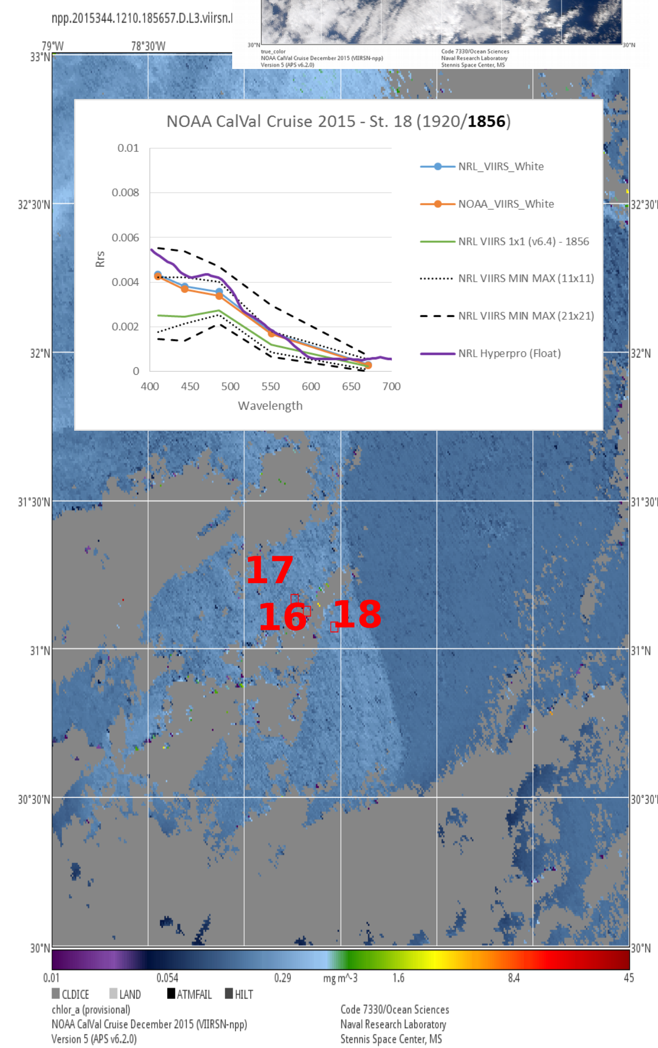






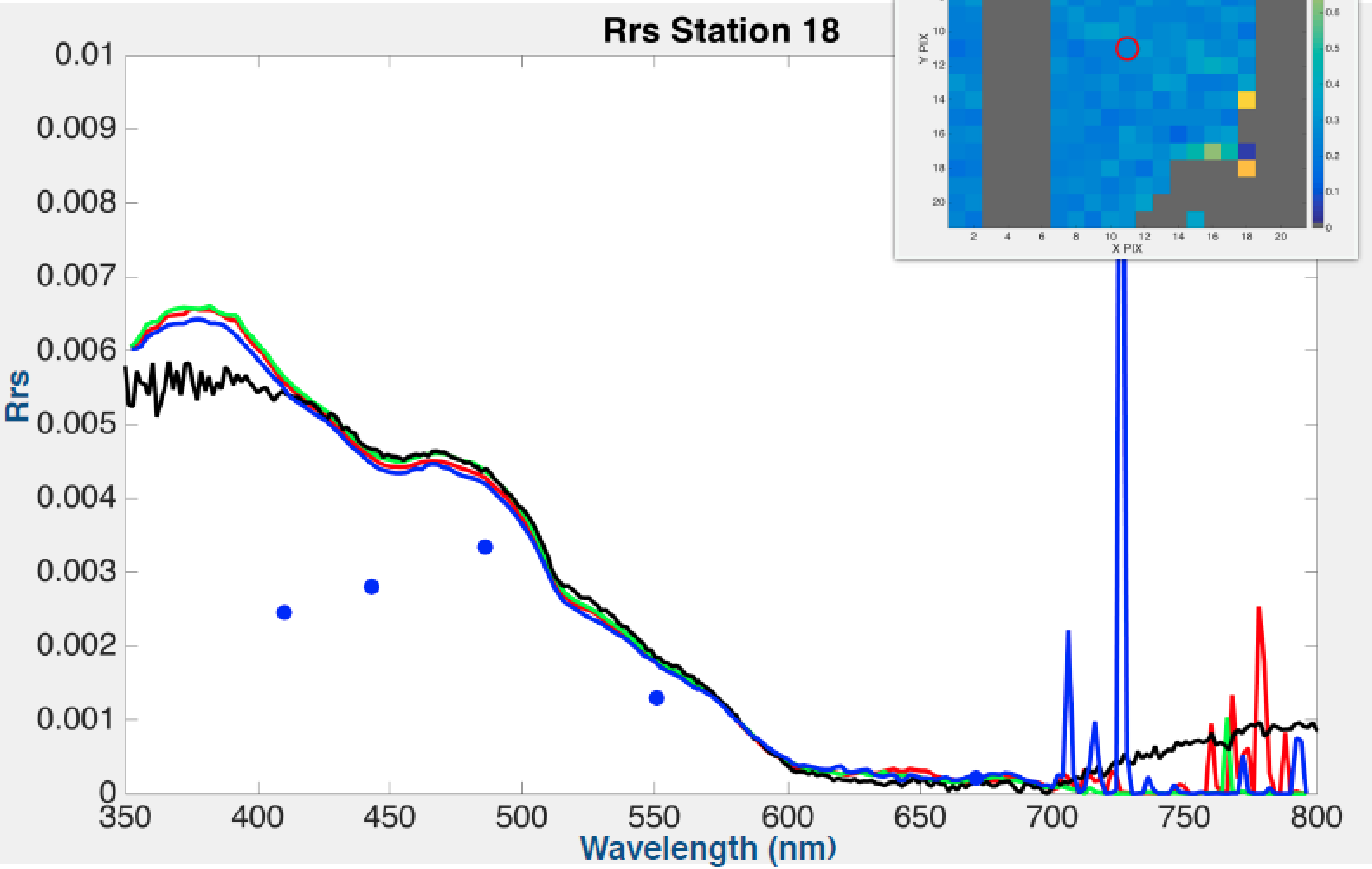




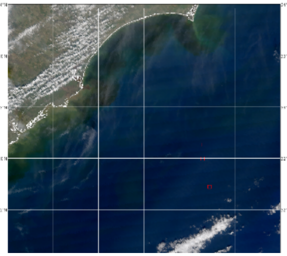


Station 18

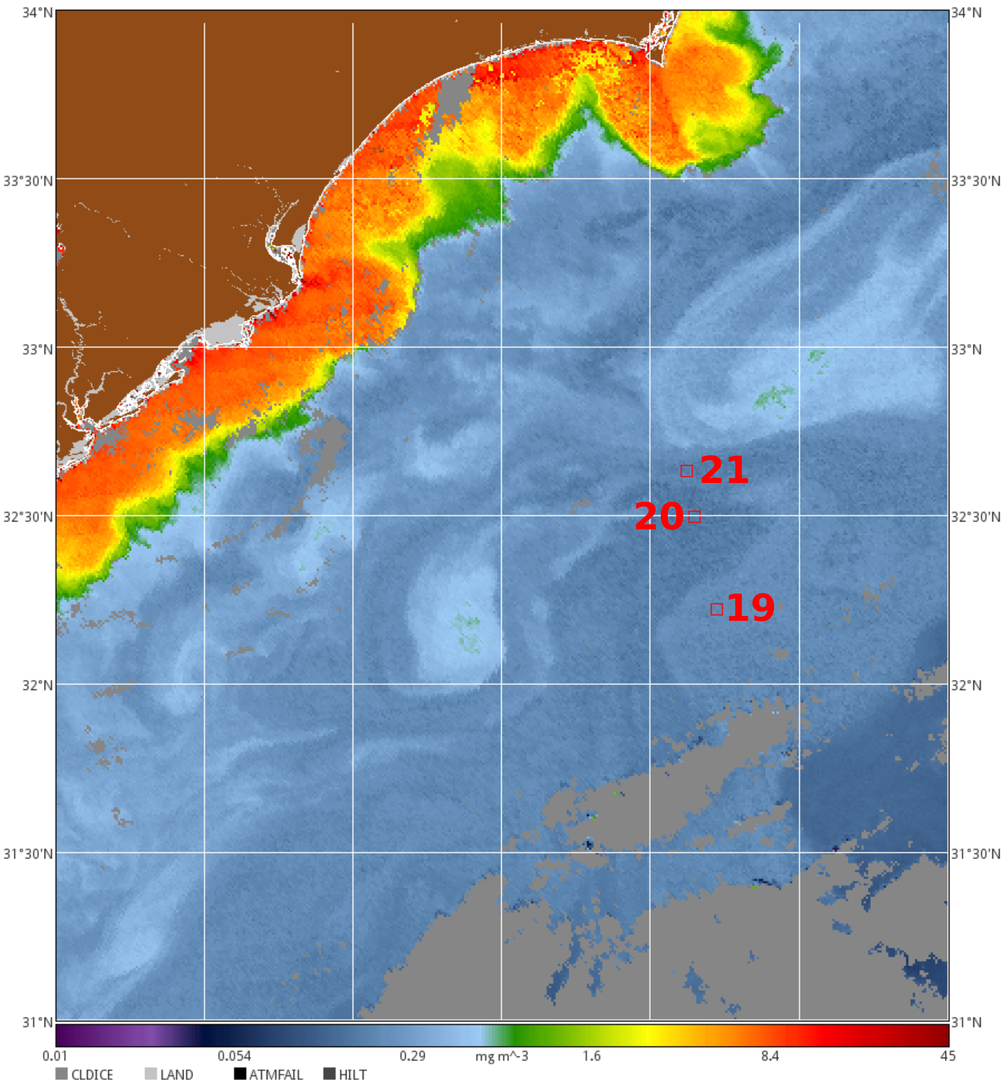
VIIRS - Blue Dots
Spectral Evolution - Black Line
HyperPro - Red/Green/Blue Lines



12/11/16 (1839 GMT)
St. 19,20,21

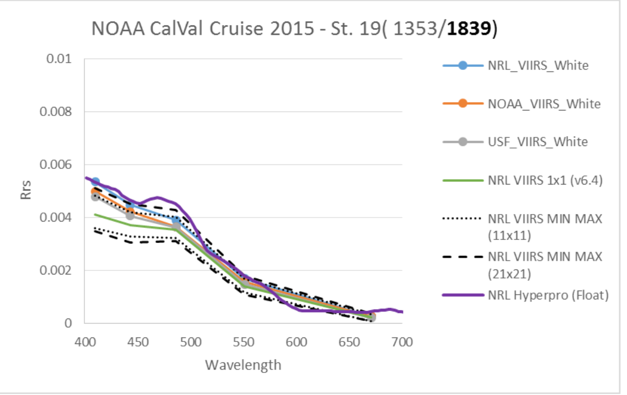


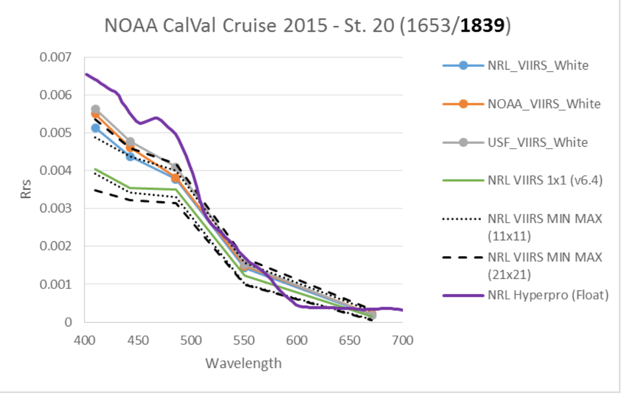
npp.2015345.1211.183926.D.L3.viirsn.NOAACALVAL2015.v05.750m.hdf
Chlorophyll Concentration, OCI Algorithm
Fri Dec 11 18:39:26 2015

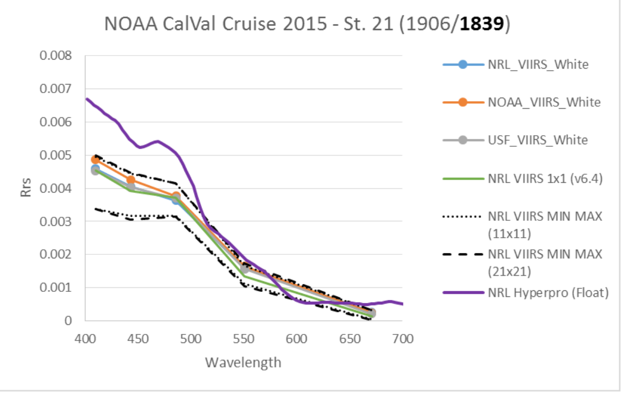


chlor_a (provisional)
NOAA CalVal Cruise December 2015 (VIIRSN-npp)
Version 5 (APS v6.2.0)

Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS

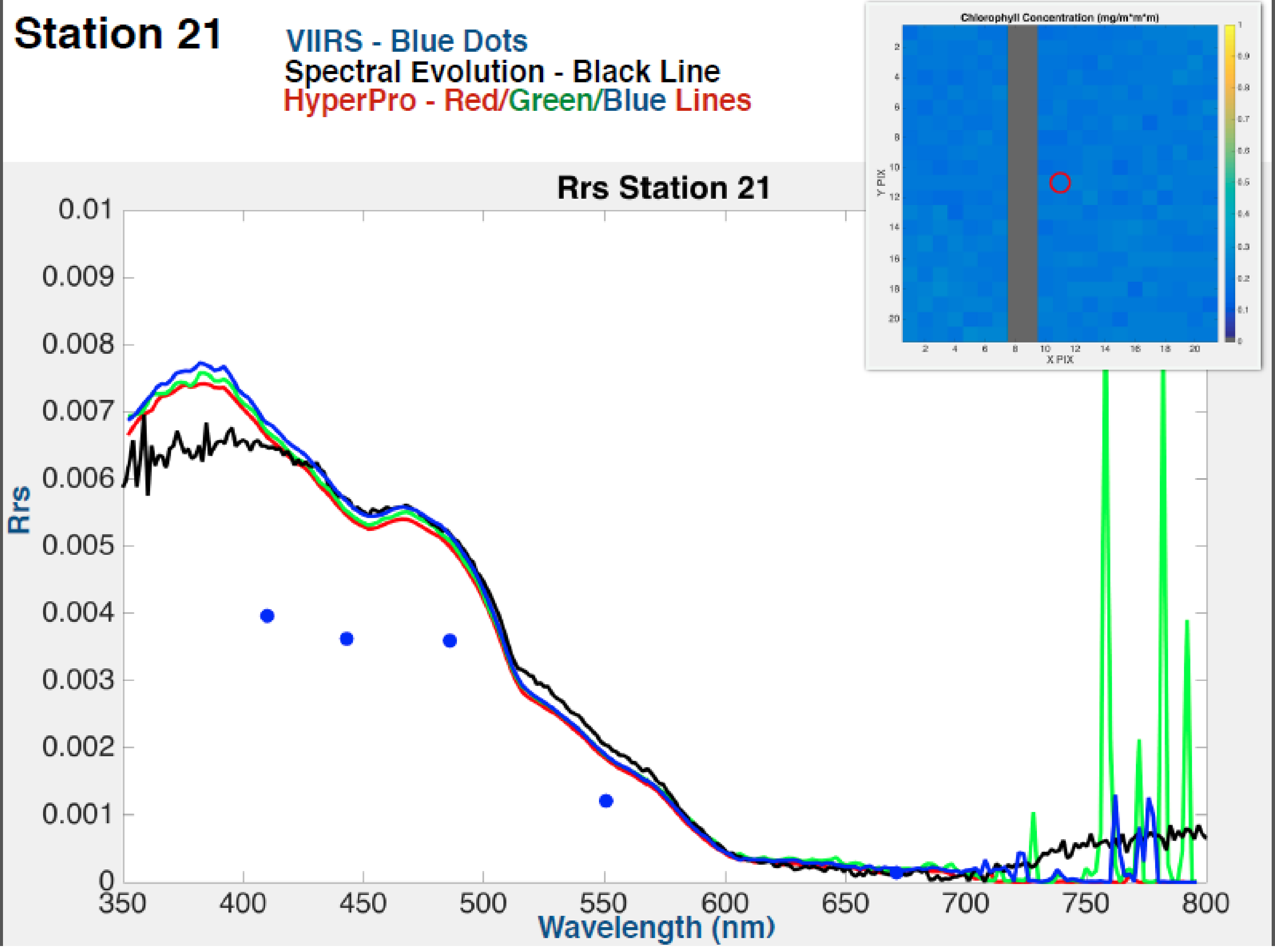




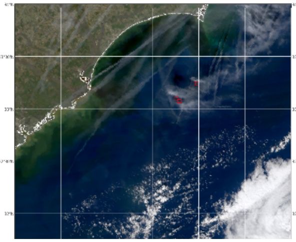


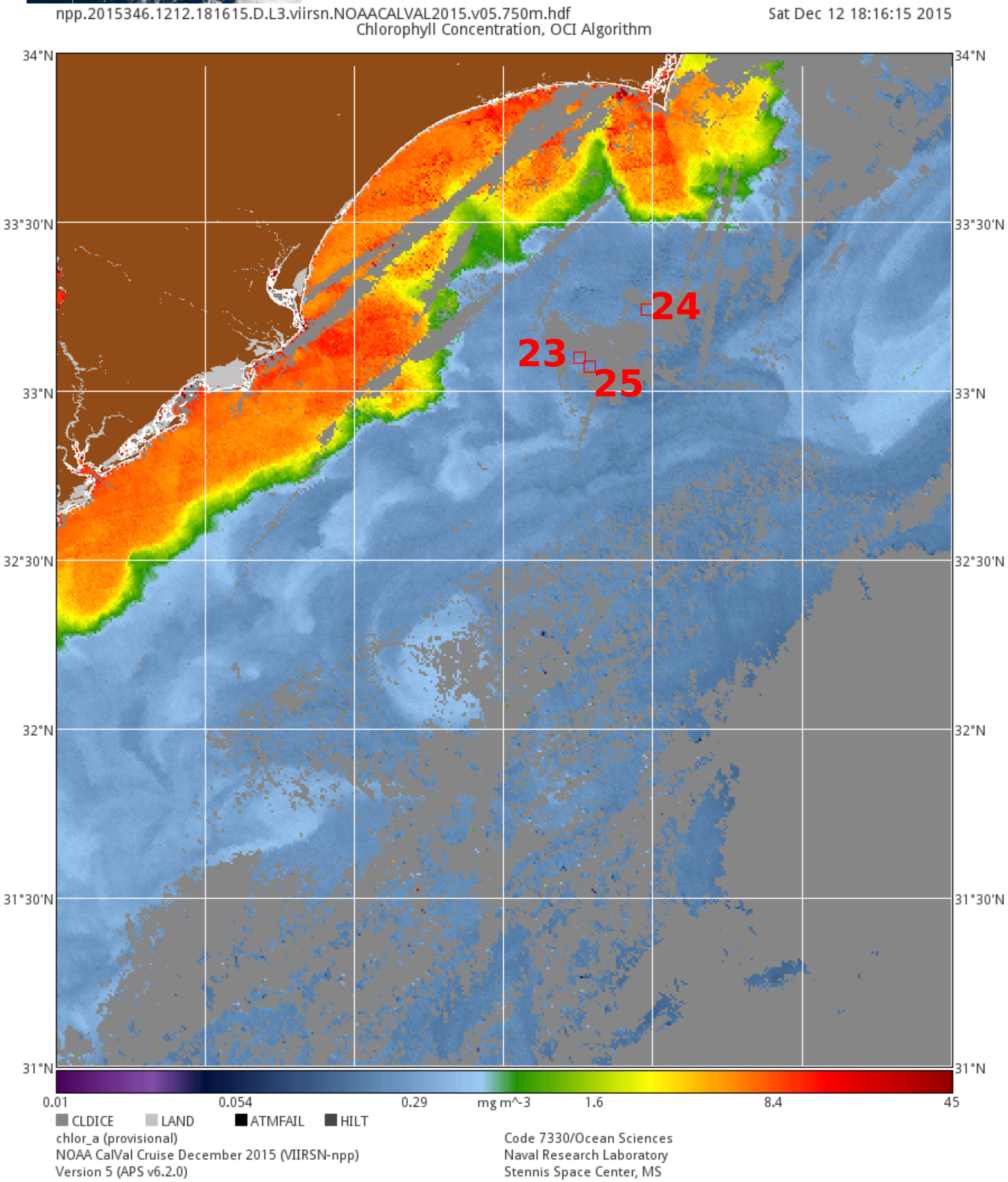
Station 21

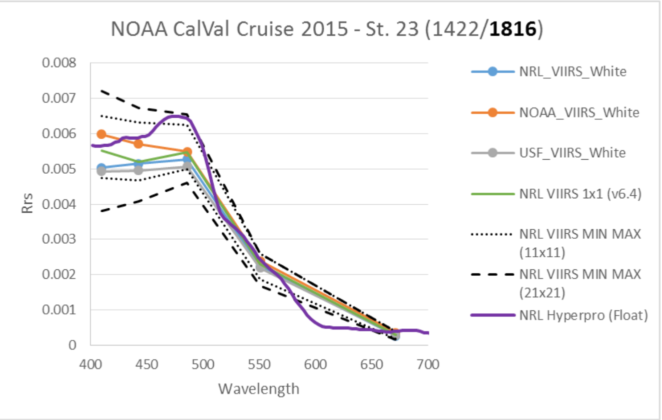
VIIRS - Blue Dots
Spectral Evolution - Black Line
HyperPro - Red/Green/Blue Lines

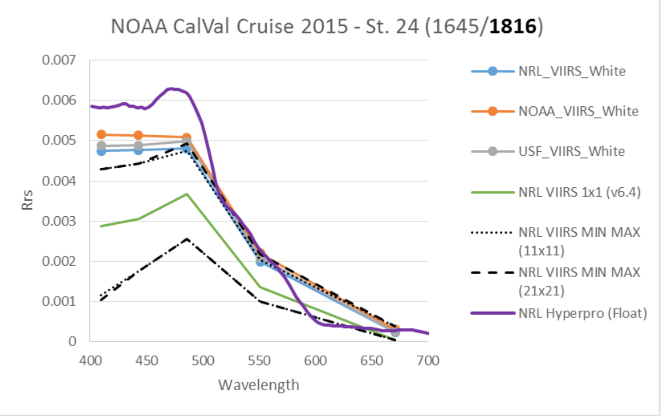


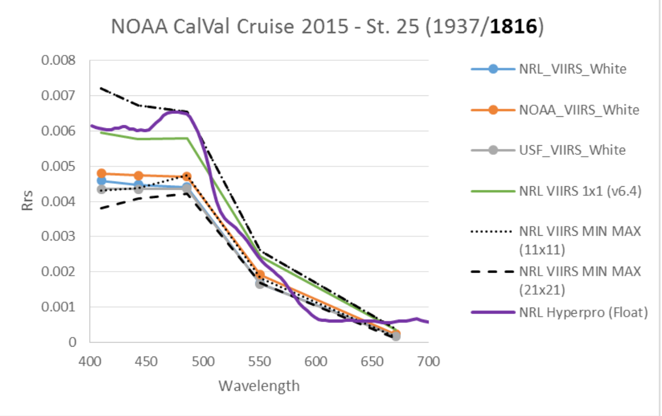
12/12/16 (1816 GMT)
St. 23,24,25





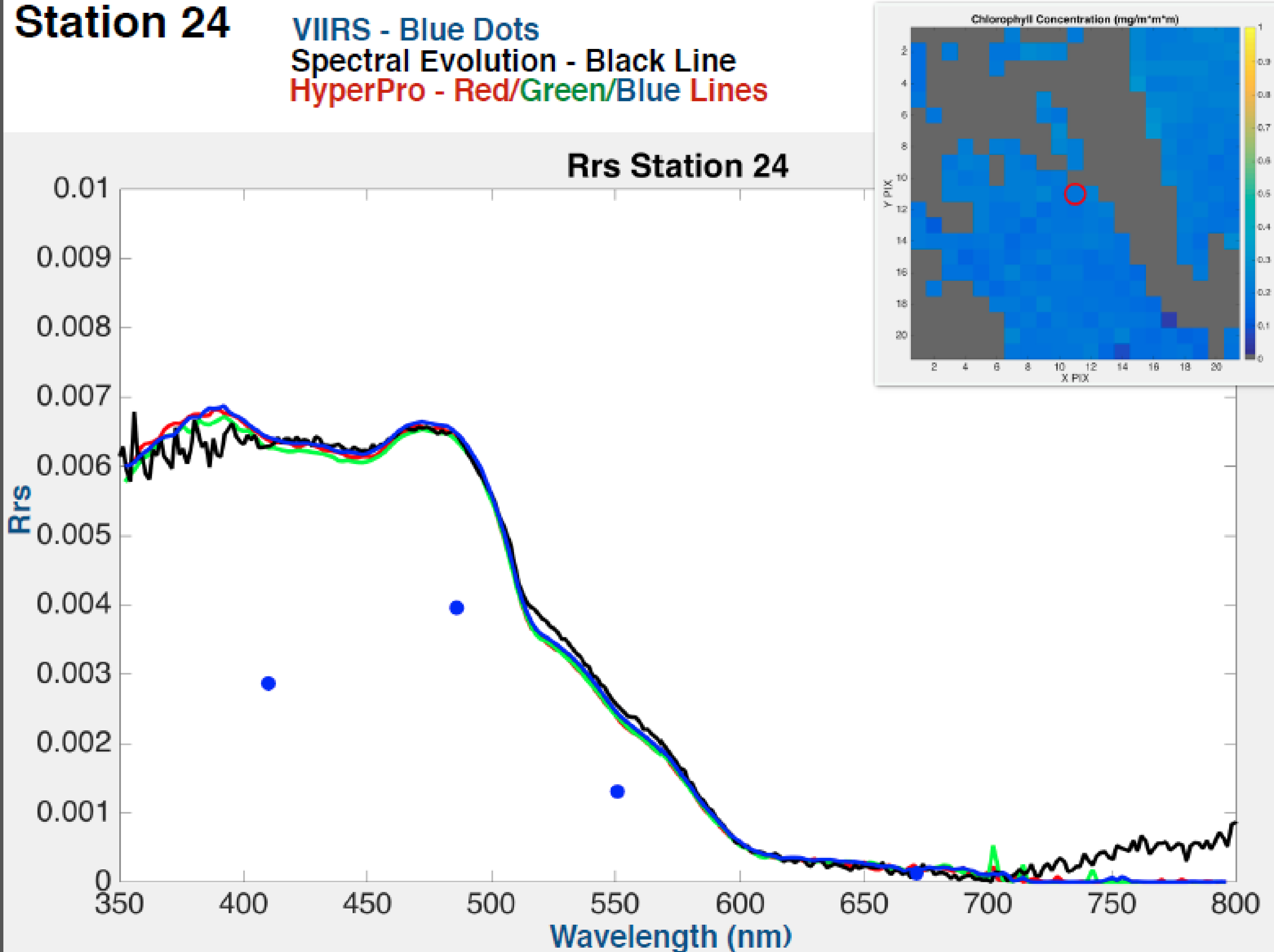




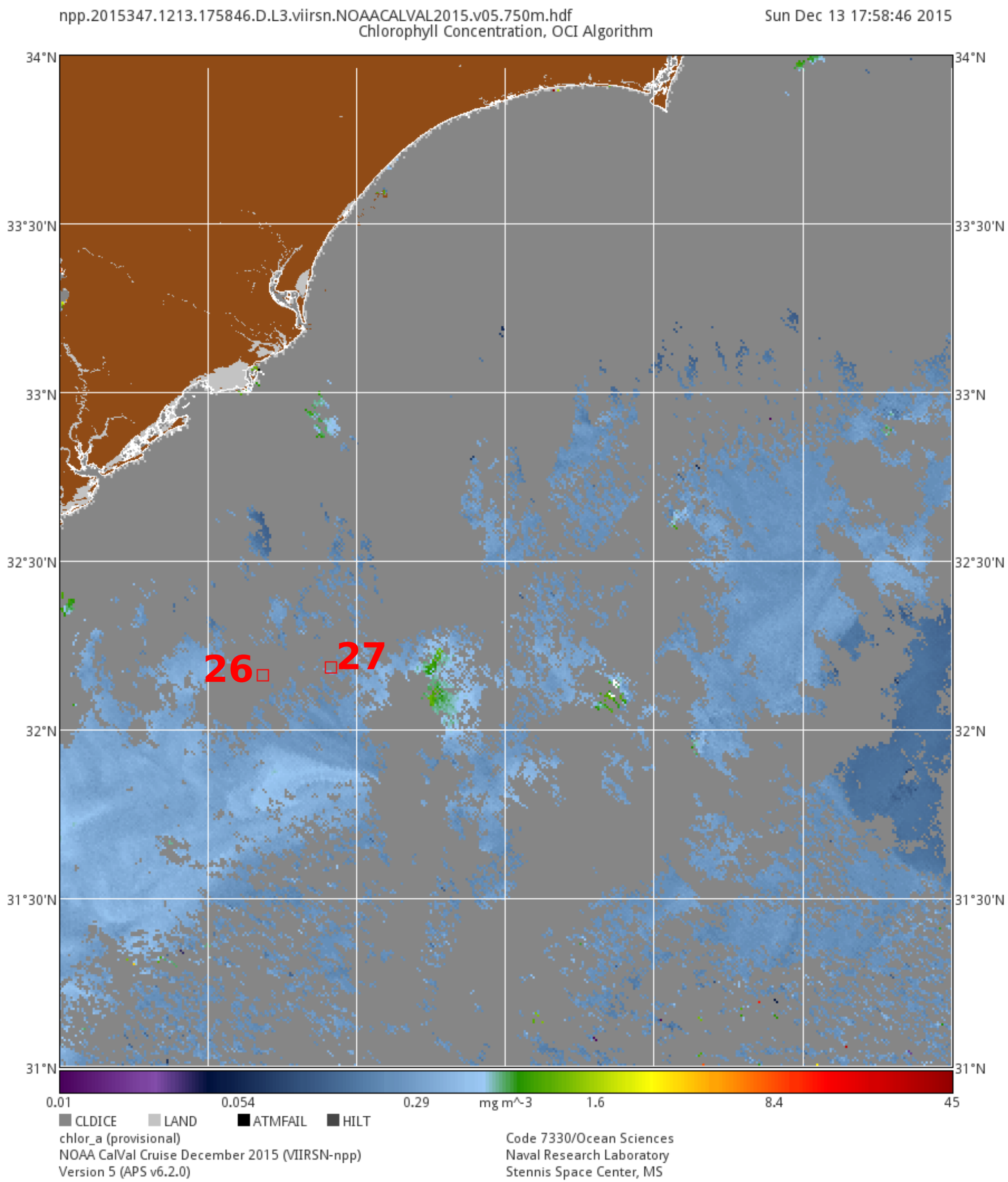


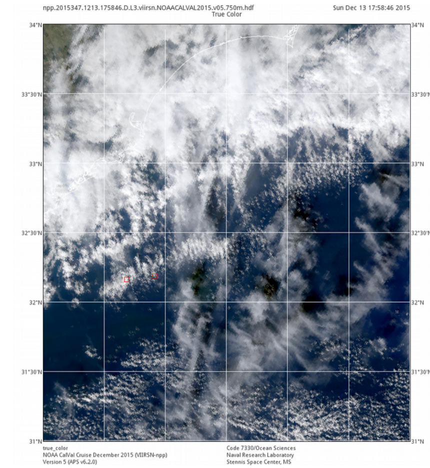
Station 24

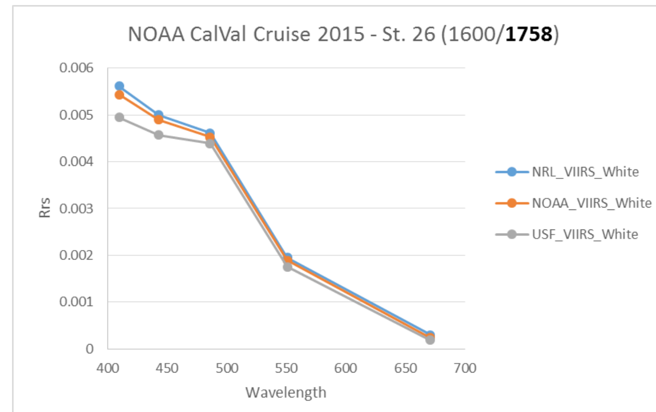
VIIRS - Blue Dots
Spectral Evolution - Black Line
HyperPro - Red/Green/Blue Lines

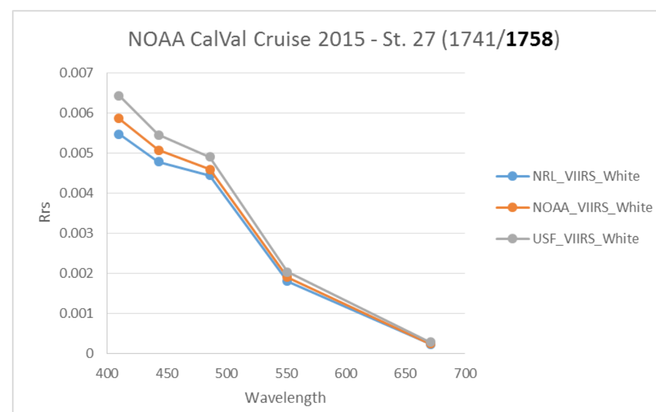


12/13/16 (1758 GMT)
St. 26,27

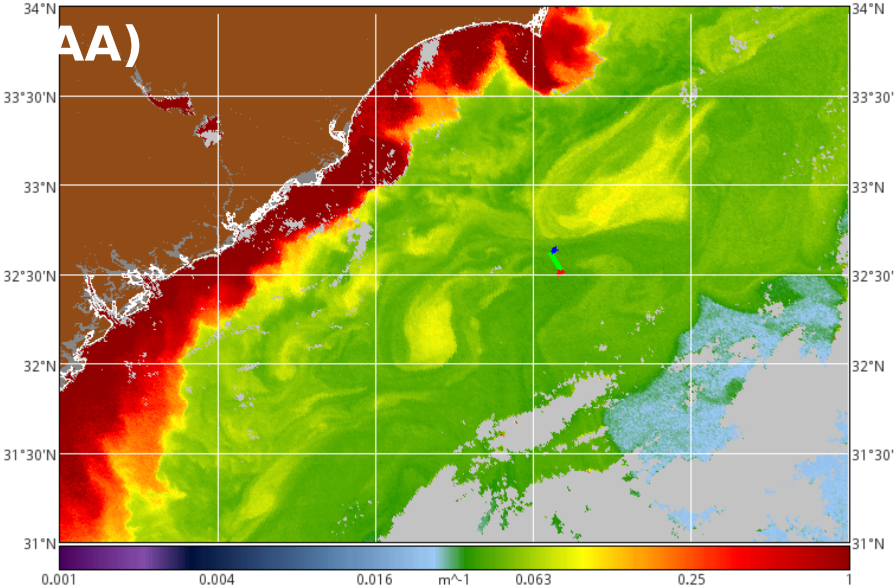






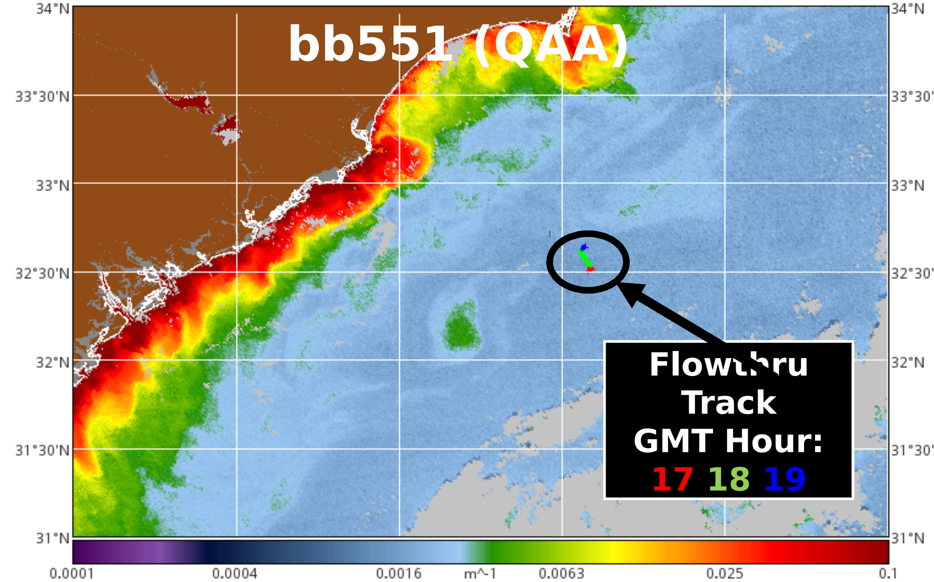


npp.2015345.1211.183926.D.L3.viirsn.NOAACALVAL2015.v06.750m.hdf Fri Dec 11 18:39:26 2015
Total absorption at 443 nm, QAA algorithm



LAND CLDICE
a_443_qaa (provisional)
NOAA CalVal Cruise December 2015 (VIIRSN-npp)
Version 6 (APS v6.4.1)
Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS

npp.2015345.1211.183926.D.L3.viirsn.NOAACALVAL2015.v06.750m.hdf Fri Dec 11 18:39:26 2015
Total backscattering at 551 nm, QAA algorithm



LAND CLDICE
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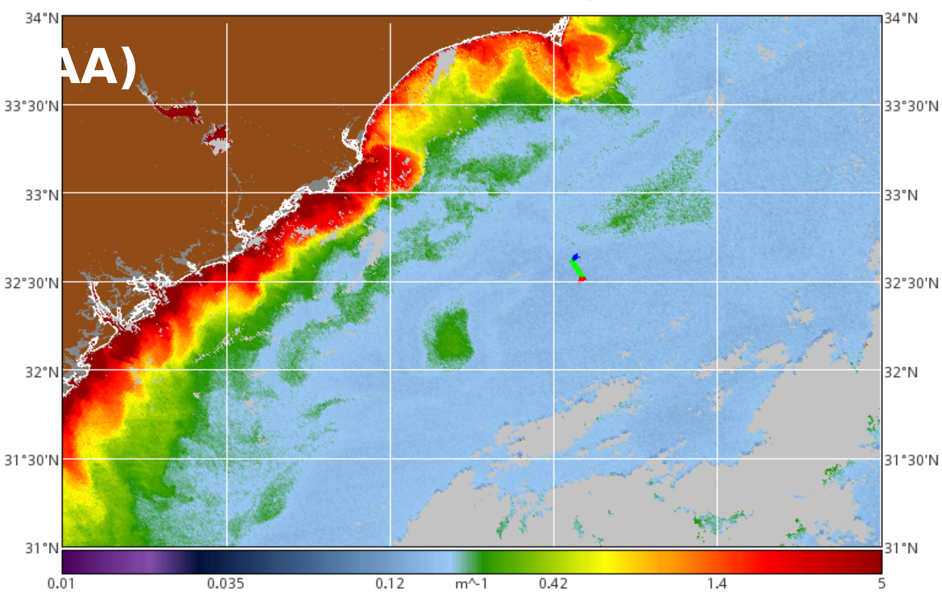
NOAA CalVal Cruise December 2015 (VIIRSN-npp)
Version 6 (APS v6.4.1)
Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS

npp.2015345.1211.183926.D.L3.viirsn.NOAACALVAL2015.v06.750m.hdf Fri Dec 11 18:39:26 2015
Beam attenuation at 551 nm, QAA algorithm



LAND CLDICE
c_551_qaa (provisional)
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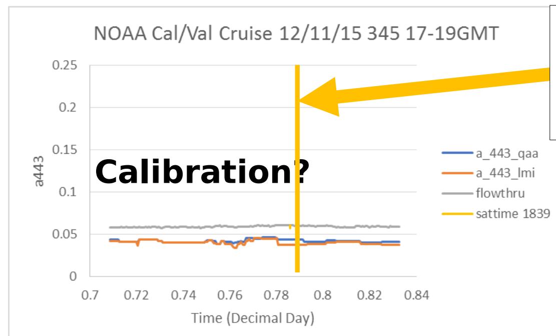
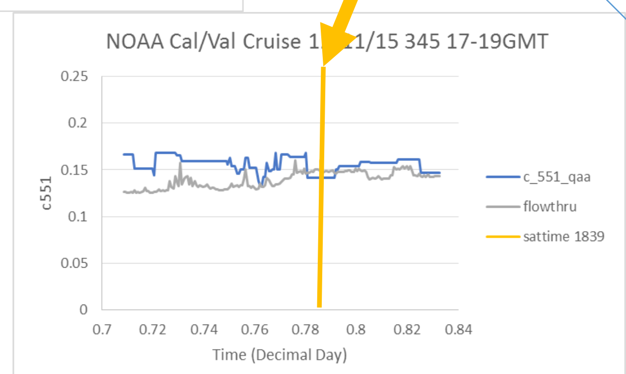
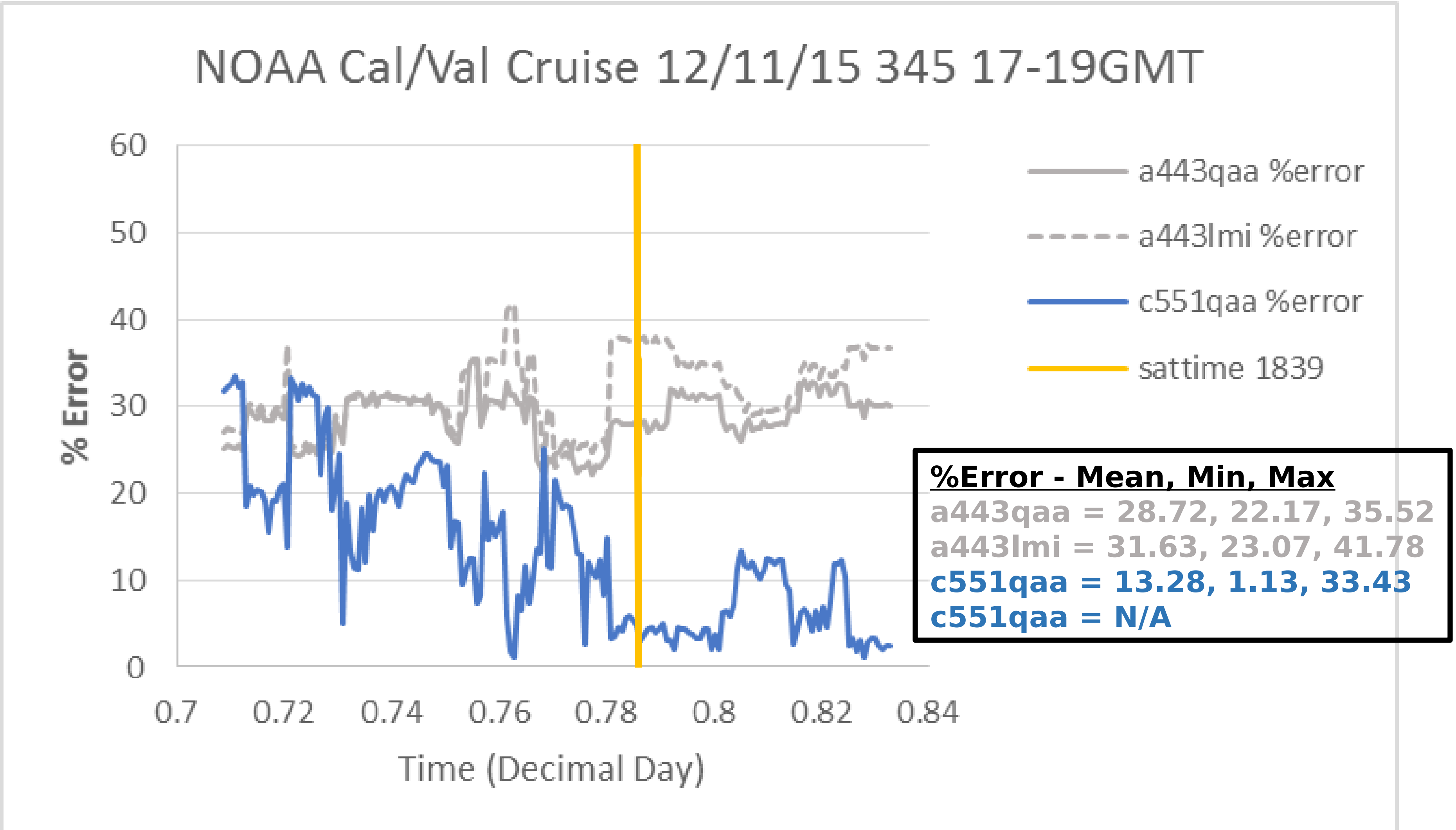
Version 6 (APS v6.4.1)
Code 7330/Ocean Sciences
Naval Research Laboratory
Stennis Space Center, MS



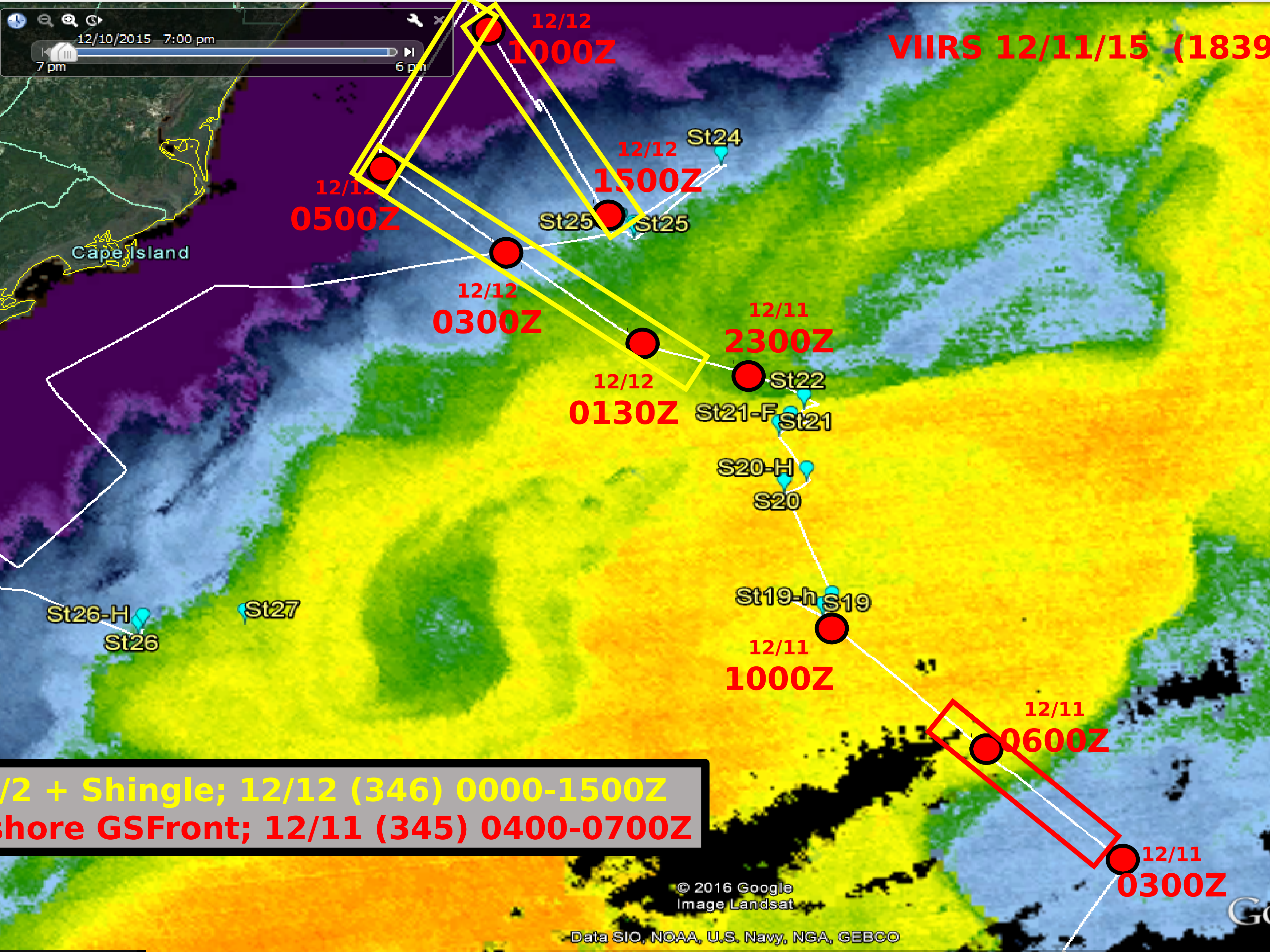
Not Bad @ Satellite Time

Binned to 1 Minute

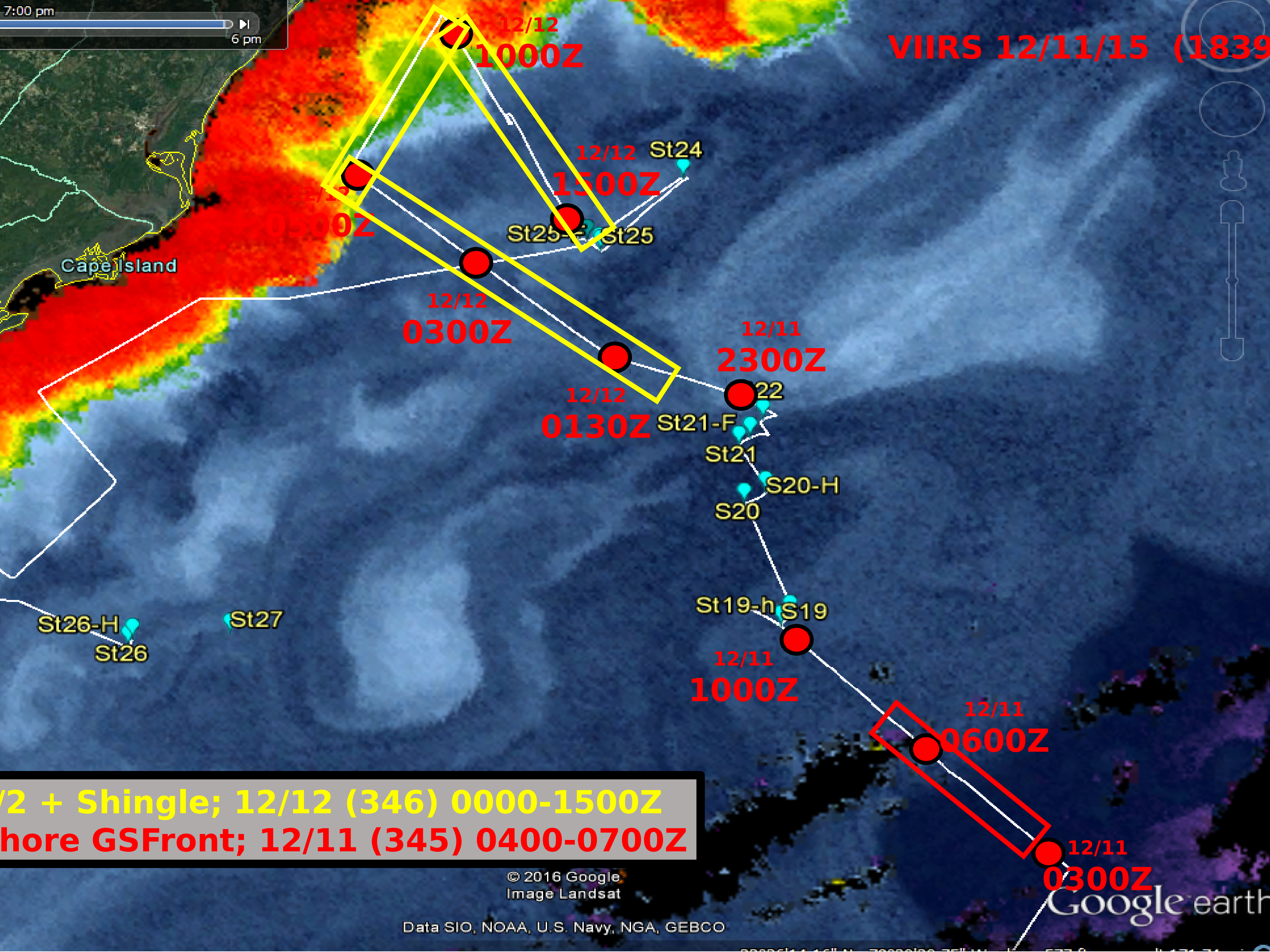




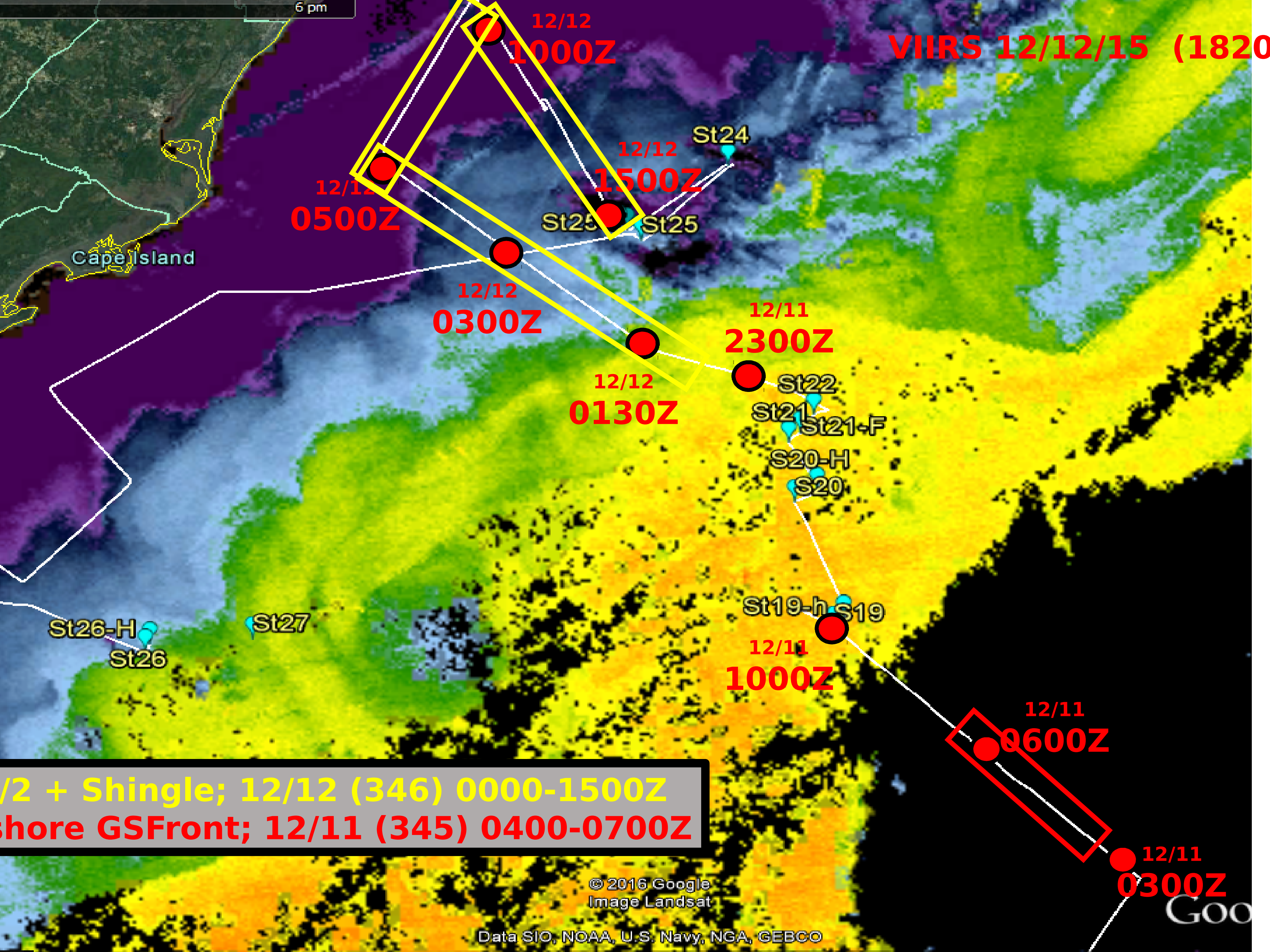
NOAA Cal/Val Cruise 12/11/15 345 17-19GMT
60
50
40
30
20
10
0
% Error
0.7
0.72
0.74
0.76
0.78
0.8
0.82
0.84
Time (Decimal Day)
a443qaa %error
a443lmi %error
c551qaa %error
sattime 1839
%Error - Mean, Min, Max
a443qaa = 28.72, 22.17, 35.52
a443lmi = 31.63, 23.07, 41.78
c551qaa = 13.28, 1.13, 33.43
c551qaa = N/A



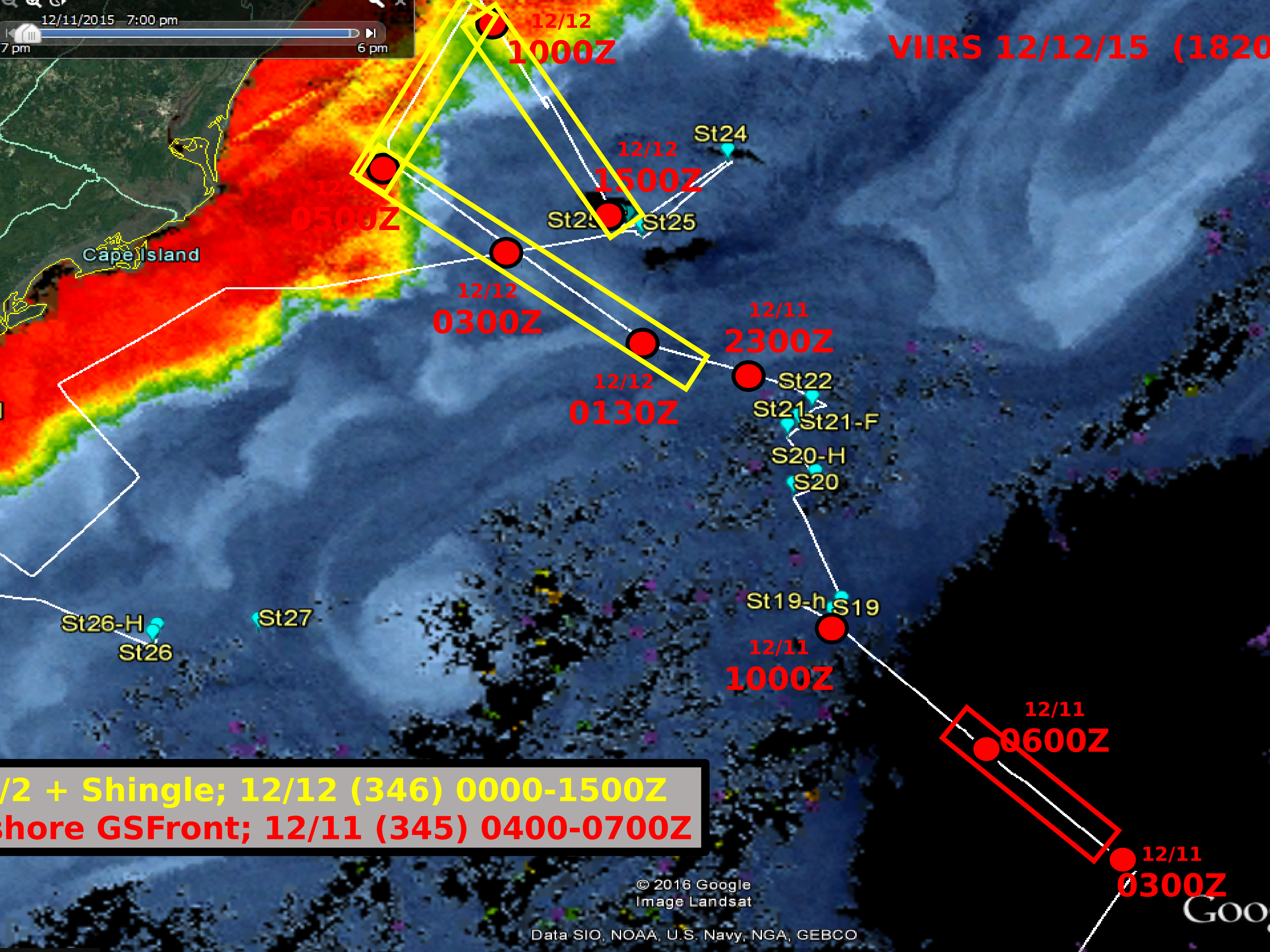
12/10/2015 7:00 pm
7 pm
6 pm
VIIRS 12/11/15 (1839
12/12
1000Z
12/12
1500Z
St24
12/12
0500Z
St25
St25
Cape Island
12/12
0300Z
12/11
2300Z
12/12
0130Z
St22
St21-F
St21
S20-H
S20
St19-h
S19
12/11
1000Z
St26-H
St26
St27
12/11
0600Z
12/11
0300Z
/2 + Shingle; 12/12 (346) 0000-1500Z
shore GSFront; 12/11 (345) 0400-0700Z
© 2016 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



7:00 pm
6 pm
VIIRS 12/11/15 (1839
12/12
1000Z
12/12
1500Z
St24
0500Z
St25-F
St25
Cape Island
12/12
0300Z
12/11
2300Z
12/12
0130Z
St21-F
St21
S20-H
S20
St19-h
S19
12/11
1000Z
12/11
0600Z
12/11
0300Z
St26-H
St26
St27
/2 + Shingle; 12/12 (346) 0000-1500Z
hore GSFront; 12/11 (345) 0400-0700Z
© 2016 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth



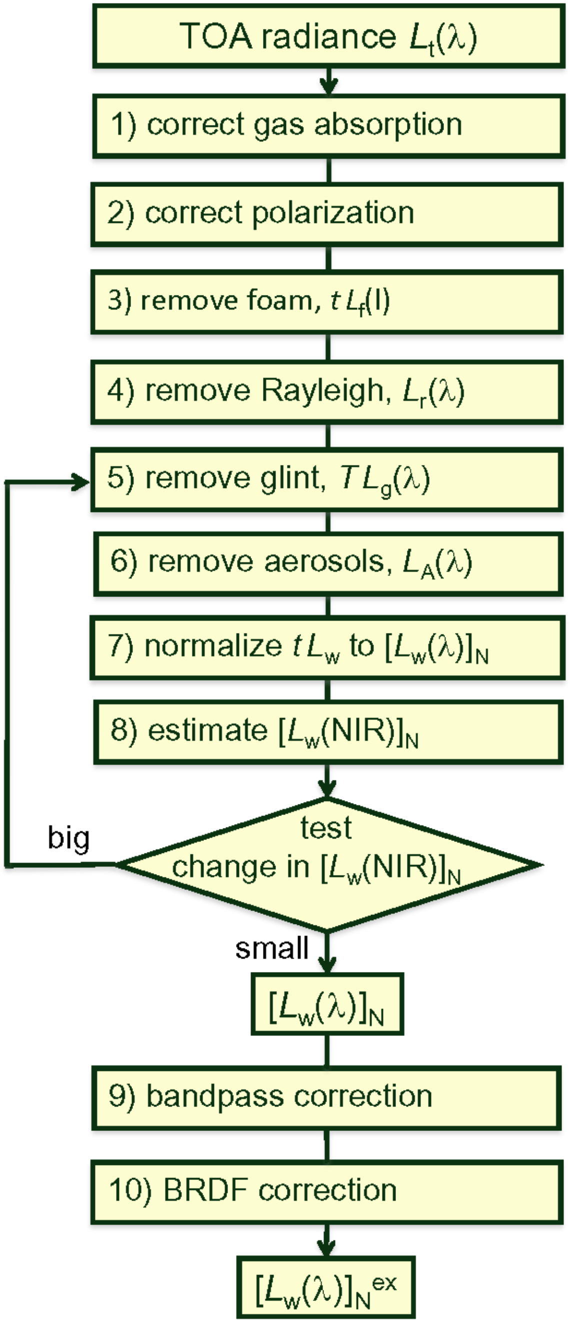
6 pm
VIIRS 12/12/15 (1820
12/12
1000Z
St24
12/12
1500Z
12/12
0500Z
St25
St25
Cape Island
12/12
0300Z
12/11
2300Z
12/12
0130Z
St22
St21
St21-F
S20-H
S20
St19-h
S19
12/11
1000Z
12/11
0600Z
12/11
0300Z
St26-H
St26
St27
/2 + Shingle; 12/12 (346) 0000-1500Z
shore GSFront; 12/11 (345) 0400-0700Z
© 2016 Google
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Goo



/2 + Shingle; 12/12 (346) 0000-1500Z

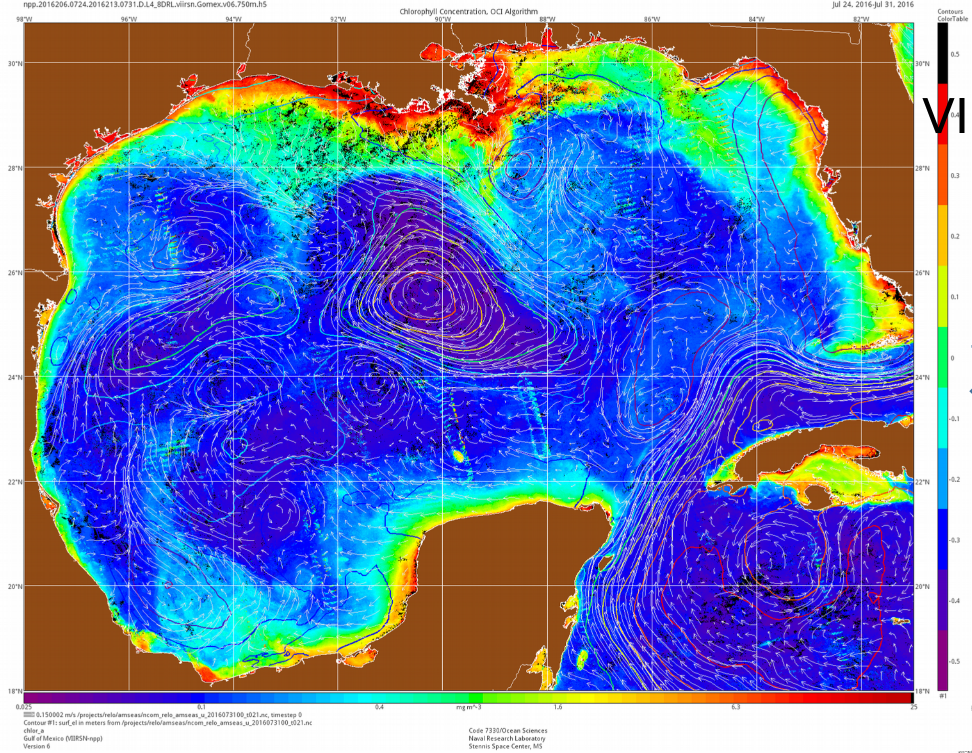
shore GSFront; 12/11 (345) 0400-0700Z

Figure: Flowchart of the atmospheric correction process.



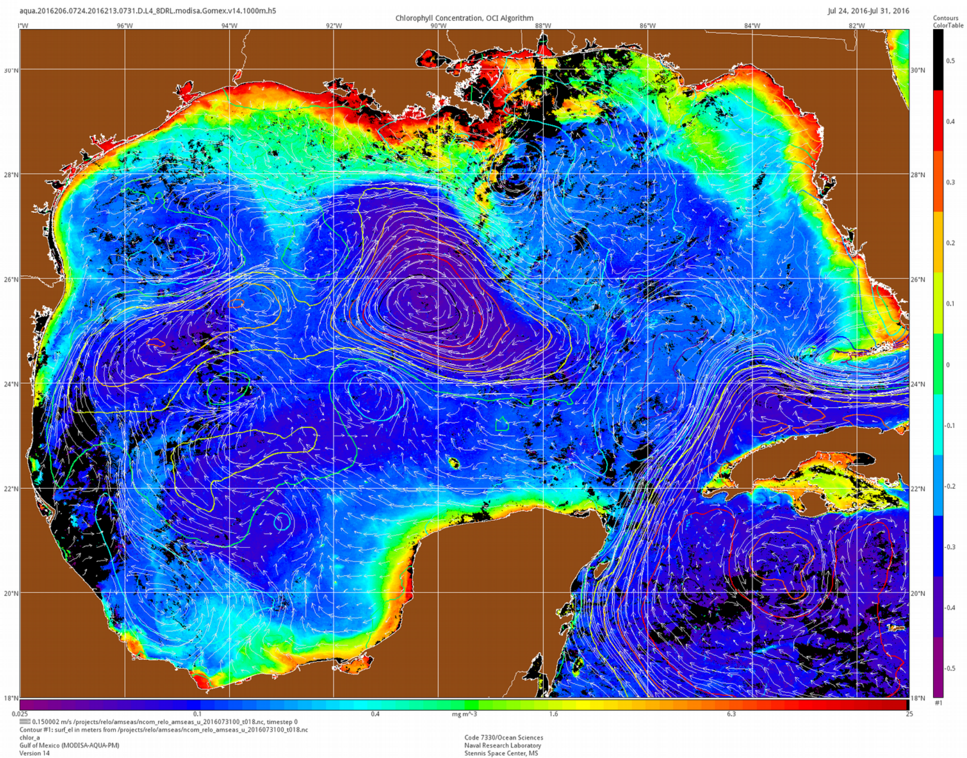
It is important to keep in mind that there are severe computational constraints on how atmospheric correction is performed on an operational basis. The MODIS-Aqua sensor, for example, collects about 1.4 terrabytes of data per day. The requirement to routinely process this amount of data (along with data from other sensors) requires that various approximations be made in order to speed up the calculations. Some of the corrections require ancillary information such as sea level pressure, wind speed, and ozone concentration, which are not collected by ocean color sensors themselves. These ancillary data may be inaccurate or missing, in which case climatological values must be used. The quality of the ancillary information impacts the accuracy of the atmospheric correction. Table [*] shows some of the ancillary data and its sources as used by the various OBPG atmospheric correction algorithms.

MODIS Vicariously Calibrated to MOBY
VIIRS Vicariously Calibrated to MOBY+AO
Spring 2016 Gain Sets
Inter-sensor Consistency



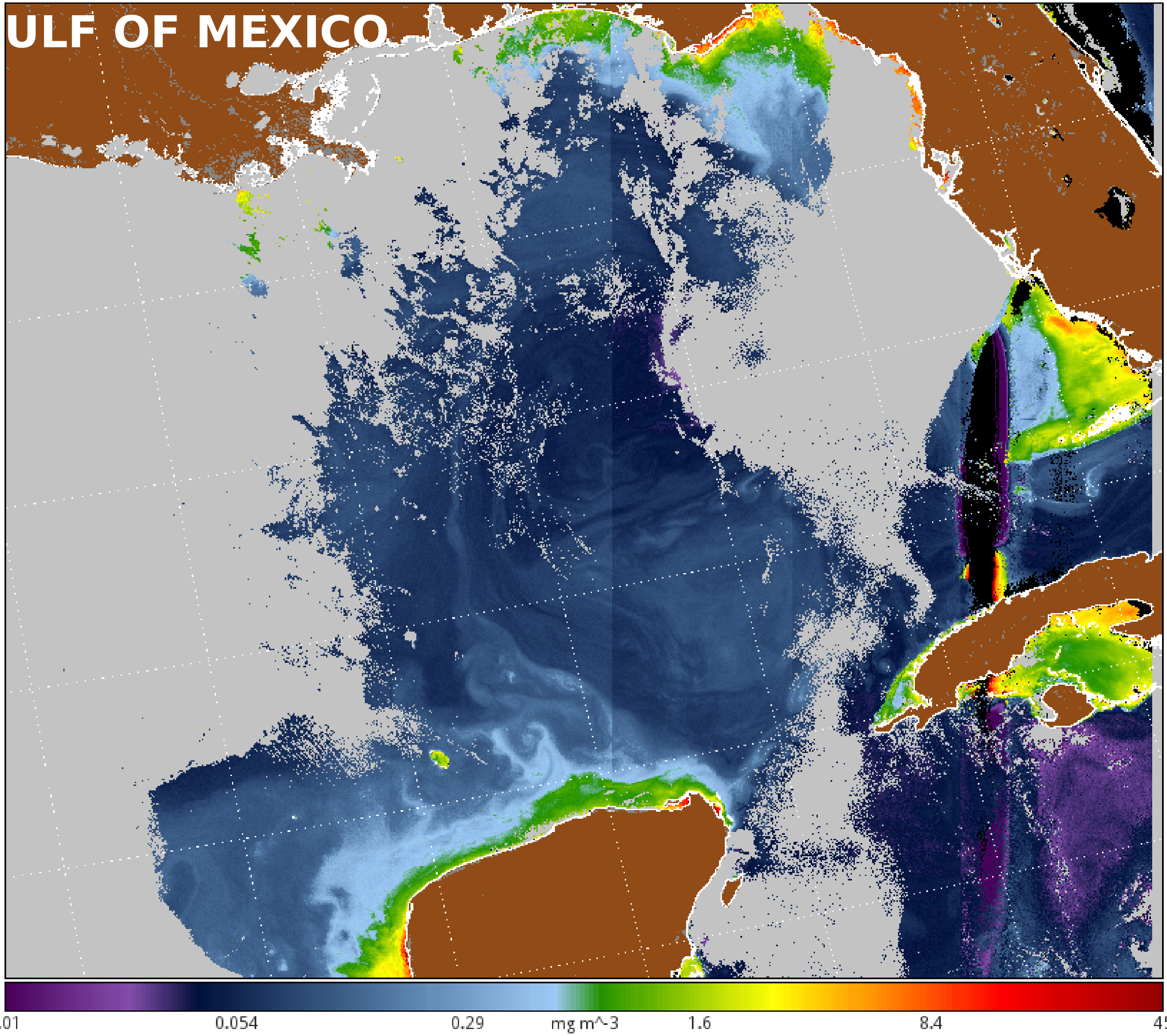
VIIRS 8 Day Rolling Composite for
July 31, 2016
Chlorophyll

MODIS 8 Day Rolling Composite for
July 31, 2016
Chlorophyll



olci.2016130.0509.155143.155443.L2.nc

Chlorophyll Concentration, OCI Algorithm



LAND CLDICE

geophysical_data/chlor_a
Sensor Frame
(null) v(null)

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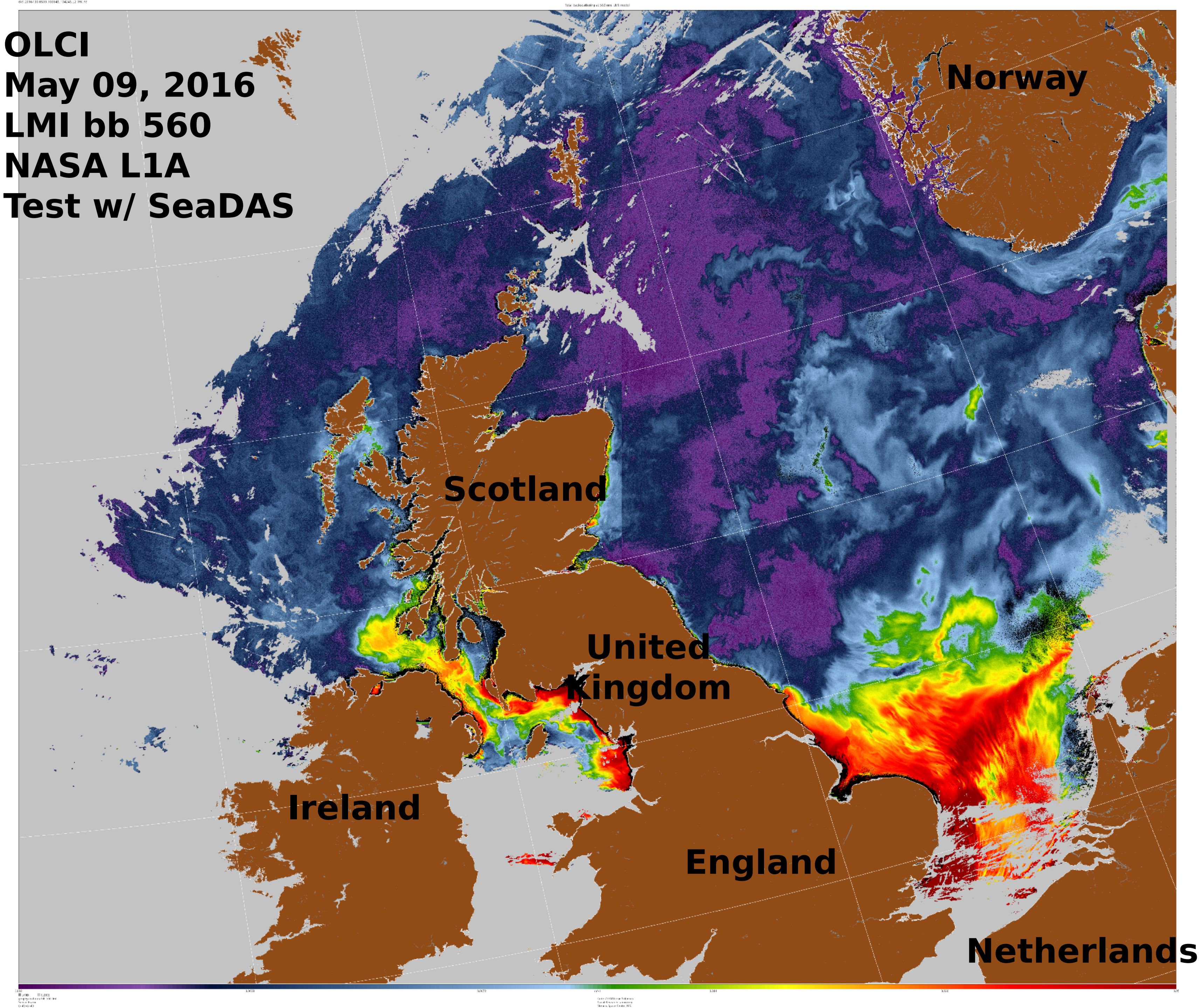
OLCI
May 09, 2016
LMI bb 560
NASA L1A
Test w/ SeaDAS
Norway
Scotland
United Kingdom
Ireland
England
Netherlands